A QUARTERLY JOURNAL OF METHODS AND INFORMATION FOR TEACHERS OF SCIENCE

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The SCIENCE COUNSELOR

Volume X ★ Number 3 ★ Sept., 1947

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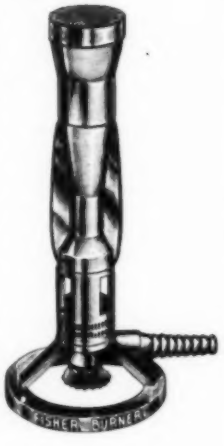

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The Science Counselor

"FOR BETTER SCIENCE TEACHING"

A QUARTERLY JOURNAL *of teaching methods and scientific information especially for teachers of science in Catholic schools. Published at Duquesne University, Pittsburgh, Pennsylvania, in March, June, September and December by*

THE DUQUESNE UNIVERSITY PRESS

Subscription Price: $1.00 per year; Canada, $1.25. Single copies of issues in the current year, 35c each.
Business and Editorial Offices at Duquesne University, 901 Vickroy Street, Pittsburgh 19, Pa.

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ANNOUNCEMENT

For many years THE SCIENCE COUNSELOR has been maintained at considerable expense by Duquesne University as a "good work" in science and education. Each year the deficit has been met cheerfully. The time has now come, however, when our readers must pay a larger portion of the ever rising cost of publication.

Beginning January 1, 1948, the subscription rate of THE SCIENCE COUNSELOR will be $2.00 per year.

Advance notice of the change in rate is given now so that those who desire to renew their subscriptions at the current rate may do so before the end of the year. New subscriptions and renewals at the rate of $1.00 per year will be accepted until December 31, 1947. At this rate advance subscriptions will be accepted for *one year only*.

We suggest early action. *H.C.M.*

The Relationship of Enzymes to Life

• **By James B. Sumner, Ph.D.** *(Harvard University)*
PROFESSOR OF BIOCHEMISTRY, CORNELL UNIVERSITY, ITHACA, NEW YORK.
NOBEL PRIZE WINNER IN CHEMISTRY, 1946.

Many scientists cannot write simply and clearly of the things about which they know most. The world-famous writer of this paper is an exception.

Dr. Sumner was the first chemist to isolate an enzyme in crystalline form and to prove it to be a protein. He has studied enzymes all his life. In 1946, he was awarded the Nobel Prize for his accomplishments in the field. In this article he discusses these important bio-catalysts in a way that even a person untrained in science can understand and enjoy. He tells what enzymes are, how they are isolated, what they look like, what they do, and how they are used in industry.

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Introduction

When the biological chemist takes a plant or animal apart, he finds it to be composed of fats and fat-like substances, carbohydrates, proteins, salts, and small amounts of substances known as extractives. The occurrence of these constitutuents does not tell what makes the plant or animal live, grow, move about, respire and reproduce. To understand the why and wherefore of these phenomena it is necessary to explain the functions of the various constituents of living matter. We know that fats, carbohydrates and proteins can be oxidized by living cells to produce energy and heat. However, the proteins possess the ability to function as enzymes, hormones, antitoxins, alexins, etc. The ability to act as enzymes is of the greatest significance and value to all living things. An attempt is made in this paper to explain what enzymes are.

Comparison

We can compare the organism, be it plant, animal or micro-organism, to a factory where automobiles are made. An organism devoid of enzymes would resemble a factory devoid of men. When the men are present, the factory begins to operate, wheels turn, raw materials are used up, products are formed, energy is consumed, a part being dissipated as heat. Likewise, in living things enzymes cause both chemical and physical processes to go on. Such processes are digestion, absorption, secretion, nerve conduction, muscular contraction, detoxication of poisons, etc.

What Are Enzymes?

Enzymes are bio-catalysts. A catalyst is any substance which initiates a chemical reaction, or hastens a reaction which is already proceeding at a slow rate. Not all catalysts are enzymes. We know of many inorganic and organic compounds which can be spoken of as "ordinary catalysts" and which are of greatest importance in industry. Finely-divided metallic platinum is one such. It is employed in the manufacture of sulfuric acid and its function is to cause sulfur dioxide to unite with atmospheric oxygen and form sulfur trioxide. This last compound unites with water to form sulfuric acid. Yet another important catalyst is hydrochloric acid. When starch is boiled under pressure with a large amount of water and a very small amount of hydrochloric acid, the starch is converted into glucose, otherwise known as grape sugar.

Catalysts enter into chemical reactions, but are not used up by these reactions, appearing unchanged at the end. Consequently, a small quantity of catalyst can, if given sufficient time, bring about a very great amount of chemical change. The enzyme, or biocatalyst, differs from the ordinary catalyst in being a product of living things. Enzymes are nearly always very sensitive to temperature and are destroyed long before the boiling point is reached. Enzymes differ from ordinary catalysts in being extraordinarily specific in their action. Each enzyme has been designed by nature for a special purpose, just as each key will open a certain lock. Thus, a lipase will digest only fats, an amylase will digest only starches, and a protease will digest only protein.

The Isolation of Enzymes

Although enzymes were discovered early in the 19th century, nearly 100 years elapsed before chemists knew what they were chemically. This knowledge resulted from the work of J. B. Sumner of Cornell University. In 1926, Sumner isolated the enzyme urease in the form of microscopic, colorless, octahedral crystals and showed these crystals to be protein. Four years later, Northrop of the Rockefeller Institute isolated pepsin in crystalline form. Sumner, Northrop and Stanley were awarded the Nobel prize in chemistry in 1946, the first two for isolating enzymes, and Stanley for his isolation of a virus. This virus, which is a protein but not an enzyme, is the cause of the tobacco mosaic disease.

The isolation of the first enzyme by Sumner came only after many years of effort. Even when urease crystals were obtained, most biochemists refused to accept the evidence. However, at the present time some 30 enzymes have been prepared in crystalline form and have been shown to be proteins, and everybody has accepted the work of Sumner and Northrup.

(Continued on Page 98)

New Tools for Science—Radioisotopes

• **By Charles Allen Thomas, Sc.D.** *(Transylvania College)*
PRESIDENT-ELECT, AMERICAN CHEMICAL SOCIETY, ST. LOUIS, MISSOURI.

The executive vice president of the Monsanto Chemical Company has graciously condensed for "The Science Counselor" a paper which he presented at the Atlantic City meeting of the American Chemical Society, in April, 1947.

Since radioisotopes have become available in relatively large quantities the possibilities of their uses in fundamental research and in applied science are being explored. Much attention has been given to their applications in medicine and biology. Here, their uses in chemistry and chemical engineering are considered.

Dr. Thomas suggests their value in studying lubrication, copolymerization, photosynthesis, and the flow of sap in trees, in detecting the pollution of water supplies, in the vulcanization of rubber, in the utilization of fertilizers, in the destruction of bacteria in foods, and in numerous other ways.

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We are now engaged in programs of research and development of the peacetime applications of atomic energy. Here, as in the war, the role of the chemist and chemical engineer is most important. Therefore, the chemist and chemical engineer should realize his opportunities in the development of this new science. But it is not enough alone to realize this importance—he must train himself by a period of study if he is to become useful in this new field and if he is to be able to handle these new tools in advancing knowledge.

First as to the availability of isotopes. These radioactive materials are now available in relatively large quantities as they are being manufactured by a chain reacting uranium pile at the Clinton Laboratories at Oak Ridge, Tennessee. I do not wish to give the impression that the application of radioisotopes is new; most of the radioisotopes produced in the pile and now being distributed were investigated prior to the war. Phosphorus 32, for example, has been used in clinical investigations for about ten years. What then have the new developments of atomic energy made possible in this field? The answer is that the nuclear reactor has made possible a more abundant source of radioisotopes! Before the advent of the pile, isotopes were produced by cyclotron bombardment, but many hours of cyclotron bombardment are required to produce a small amount of material. The isotopes which can be produced by slow neutron absorption are obtained from a pile in quantities from a thousand to a million times larger than from the cyclotron.

With your permission I would like to suggest some uses for the radioisotopes. These suggestions are not entirely my own, but have been proposed both in the project and in non-project memoranda, and by many individuals. Particularly I am indebted to Drs. W. E. Cohn, J. W. Irvine, P. C. Tompkins and W. H. Sullivan. These suggestions are presented solely as a provocation to thought and to stimulate, perhaps, the application in your chosen field. No guarantee is given even to the practicability of all the suggestions—they are given mainly to point out their possibilities.

Much has been written and said about the use of radioisotopes in the field of medicine and biology, but here I would like to limit my remarks to the opportunity in the fields of chemistry and chemical engineering. Radioisotopes are of great value in fundamental research, but the possibilities in applied chemistry and chemical engineering should not be overlooked.

One of the most promising uses for Carbon 14 is in furthering the study of that most important reaction —photosynthesis. We are hopeful that photosynthesis investigations will be greatly aided by the use of radioactive carbon, insomuch as the products can be isolated and identified. For example, beginning with carbon dioxide we could obtain radioactive hexose, and by adding the hexose to a plant it could be determined whether or not this substance was an intermediate in the production of an acid like citric acid.

In copolymerization, where polymers are produced by two materials, the problem often arises as to the composition of the polymer and also whether it is a real copolymer or whether it is a component polymer with the inactive compound imbedded in it. The use of radioactive carbon in a study of this kind, and in the question of polymerization in general would be very helpful.

In fundamental chemistry tracers are being used and could be used more profitably in thermodynamic studies and in studies of reaction kinetics; also in studying the diffusion of gases in solutes and in various solvents.

In applied chemistry a host of opportunities present themselves. For example, the role of sulfur in the vulcanization of rubber has long been studied. It would seem that it would be possible to learn more about this reaction by the use of radioactive sulfur. Here one could follow the forms of combination and the distribution of sulfur in vulcanized rubber.

Let us look at the opportunities for tracers in the field of chemical engineering. One of the paramount problems in distillation is the determination of equilibrium data and the measurement of operating efficiencies. Radioactive tracers may be used to obtain

binary equilibrium data and vapor-liquid information of precision, particularly in dilute ranges. In the determination of the number of plates in a high efficiency fractionating column it is often difficult to analyze for purity at the top and bottom of the column. The addition of suitable radioactive tracers into the feed would greatly simplify this problem. Such a method might be particularly useful in the separation of hydrocarbons, particularly hydrocarbons of low molecular weight such as ethane, ethylene, propane and propylene. This technique would also be useful in getting data on columns used for the purification of oxygen, nitrogen, and the rare gases such as xenon and argon. Often in attempting to produce high purity materials by distillation it is difficult to obtain automatic control where the impurities are very dilute. Tracer technique could be used to follow these impurities and actually be used for control and continuous process indication. In any distillation where numerous samples are to be withdrawn the use of tracers offers an easy method of analysis, particularly in multicomponent systems. In experimental studies of batch distillation, radioactivity can provide an easy means of following the movement of low boiling components up through the fractionation column. The progressive concentration of these components can be checked at various points as equilibrium is approached.

In some chemical engineering processes it is desirable to scrub materials from gases so that they are present in extremely small quantities in the exit gas. Radioactive tracers would simplify the analytical problem. The efficiency of an absorption column could be more readily determined by analyzing the excess gas phase. In fact, absorption data in the very dilute ranges could be studied intensely.

Tracer procedures have proven to be of great value in detecting the presence of finely divided solids in liquids which have passed through a separation process. Thus an easy means of calculating separation efficiencies for centrifugation, filtration, and the rate of settling of a precipitate in a closed tank, now exists.

The linear velocity of liquid flow in a pipe can be measured by timing the successive appearance of radioactivity at two points along its length. This method is of special value where circumstances are such that sampling is impossible, because the radiations can be measured through the pipe walls.

Lubrication is tremendously important both to the mechanical and the chemical engineer. The use of tracers in studying problems of wear and lubrication and the measurement of metal transfer between bearing surfaces seems opportune. Metal transfer between similar surfaces could be measured accurately. The sensitivity of the method makes possible the measurement of transfer between extremely hard surfaces where the transfer is very small. Results such as these should be most valuable in understanding the mechanism of frictional phenomena.

In the field of industrial hygiene and public health, tracers might be used to detect pollution of a water supply, such as investigating underground connections between bodies of water. Also, drainage from various sewage disposal systems, such as cesspools, could be investigated.

The toxicity of factory air is an important consideration to our industrial workers, and at times it is a difficult problem. It should be possible to devise a radiotracer analytical technique for analyzing minute amounts of compounds which are toxic to the human being.

In the field of agriculture many possibilities present themselves. The first that comes to mind, and it is being worked on, is the utilization of fertilizers. Tracer studies here give information on the efficiency of a particular fertilizer—how it is picked up by different plants with different modes of application. Of current interest is the utilization of fertilization through leaf spray. Tracers offer a splendid opportunity of studying this phenomenon and other plant nutritional factors.

Sap flow in dormant trees in the winter months is not well understood. At the present time radioactive phosphorus is being used as a means of following the daytime sap flow through dormant maple trees. This work is being done at the New Hampshire Agricultural School.

Likewise in agriculture, tracers should prove of value in following the distribution of inorganic constituents through the soil and testing the fertilizer requirements of different soils.

The insect menace is ever with us. It has been suggested and work is being done on the use of small amounts of radioactive materials sprayed on migratory insect pests. In this way it is possible to determine their migration speeds, origins and routes of travel.

Thus there are many suggestions for the use of radioactive materials as tracers. Now I would like to give a few examples of the opportunities for using a nuclear reactor, or radioisotope, as a source of radiation. Dr. Milton Burton and Dr. W. F. Libby in a discussion pointed out that it is possible to measure chemical bond strength accurately if a sufficient number of monochromatic neutrons of low energy could be made available. The idea was simply to select neutrons of various energies and impinge them on a particular organic compound. The initial appearance of a chemical reaction would therefore be associated with the lowest bond strength in the molecule. In the case of a hydrocarbon, this would be the weakest carbon to carbon bond in that particular molecule. In the case of other organic compounds, certain bonds might be expected to break at even lower energy levels.

Work is now going on with the so-called neutron spectrometer in conjunction with the pile at Clinton,

(*Continued on Page 99*)

Reptiles and Amphibians in the Classroom Zoo

• **By M. Graham Netting, M.A.** *(University of Michigan)*
CURATOR OF HERPETOLOGY, CARNEGIE MUSEUM, PITTSBURGH, PA.

You need not be a biologist in order to enjoy this delightful article on classroom pets, but every teacher of biology will learn something by reading it.

Although far from the classroom, the eminent Mr. Netting understands the difficulties of operating a school menagerie successfully. He advises the procuring of local, easy-to-keep reptiles and amphibians, and outlines some helpful time-saving procedures. The suggestion that high school students can discover biological facts worthy of publication is a stimulating one.

You will like the story of "Victor-Victorine."

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Many important phases of biology require such uninterrupted laboratory investigation that it is often impossible for a person dedicated to the study of life to see much of it, or to observe its manifestations in more than a few species of laboratory animals. It is vitally important, therefore, that the investigators of the future should become as familiar as possible with living animals during the course of their training. The best way, of course, to become well acquainted with animals is to visit them at home, but this means field trips, and in these days of overcrowded schools, overworked teachers, and large classes, the amount of field work that can be included in the beginning curriculum is sadly limited.

A classroom zoo must never be thought of as an adequate substitute for field study, but even a few living animals can do much to enliven the teaching of zoology and can provide opportunity for direct observation of many aspects of animal behavior. Most biology teachers recognize the advantages of keeping classroom pets, but many avoid doing so because of the extra labor that their care entails. I propose, therefore, to recommend for the school menagerie some of the toughest, easiest-to-keep reptiles and amphibians, and to suggest certain time-saving procedures.

Busy teachers should concentrate upon local animals. It may appear easier to order a distant creature from a dealer than to collect a local species, but it's not the obtaining that matters; it's the upkeep! Exotic specimens often arrive in weakened condition and they usually have food preferences, temperature optima, and humidity requirements difficult to satisfy. Local animals may have less appeal but they have the same life processes and serve equally well to illustrate biological principles.

Small groups of students should be charged with the care of specific animals, and should be encouraged to record and to report their observations. Many details of the life histories of common species are entirely unknown and questioning youngsters can discover many facts worthy of publication. Uncritical lists of foods eaten are available for most species, but there are few tabulations of foods refused, and still fewer analyses of preferred, seasonal, and staple foods. The drinking habits of many creatures are complete mysteries.

Cages should be small enough for easy handling and cleaning, and they should be furnished as simply as possible. For snakes, a glass-fronted wooden box, with a screen-wire, lift-up top, is generally most satisfactory. These boxes should be built in several sizes; a snake that usually rests in a five-inch coil does not require three square feet of floor space. Folded newspaper is one of the most utilitarian floor coverings; it is smooth and soft and can be replaced rapidly when it becomes wet or soiled. Minimum furnishings are a water dish large enough to permit the snake to immerse itself, a branch for climbing, and some type of shelter —a piece of cork bark is ideal but many substitutes may be used. Cages should be kept in a warm sunny place, but shade is as necessary as sunlight. Snakes regulate their body temperatures by basking for awhile and then retiring to shelter to cool off. Ten minutes enforced exposure to a mid-summer, mid-day sun is often fatal.

COPPERHEAD—Not recommended for the classroom zoo.

Never keep more animals than can be cared for properly. Three or four specimens in fine condition make a better impression and are better teaching exhibits than a dozen half-starved victims. If your zoo becomes crowded, mark the local specimens if possible and release them in a suitable habitat in or near the campus. Wise teachers often keep a land turtle for a month or so, release it to find its own food and winter quarters, recapture it the following spring, and repeat the cycle. Where box turtles or wood turtles are moderately common, each individual on a campus should be numbered by notching or drilling a hole in a particular marginal scute. Then as each is apprehended it can be remeasured, reweighed, and released if unwanted.

The following list is by no means a complete roster of hardy amphibians and reptiles. I have chosen as representative of each native order one or two species that adapt themselves to captivity; many other species would be equally satisfactory. The order of arrangement is not taxonomic; it is in descending order of human interest, an entirely unscientific "Hooper rating" based upon visitors' reactions to my changing laboratory pets.

The first requirement for a classroom snake is that it be harmless. Some readers, I am certain, will accuse me of being over-cautious and will testify that they have kept poisonous snakes for long periods without incident. Even they will agree, however, that among ten biology teachers there may be one absent-minded enough to forget to lock a cage occasionally, and in a hundred there may be a show-off. Or, the teacher may be ever vigilant and a cleaner's mop handle may break a glass cage accidentally. One copperhead loose in a school can start such a wave of hysteria that the school board loses all sense of proportion and passes an edict forbidding the keeping of *any* live animals. A few years ago a visitor wandered into a university laboratory, pried open a locked cage, and poked a rattlesnake with a ruler to see what would happen. It did! Of course my warning is aimed at the high school biology classroom and the beginning zoology laboratory; advanced college classes may have occasion to study poisonous snakes, and graduate students may require them for experimental investigations.

The second requirement is that the pet snake have a good, and preferably a rather undiscriminating, appetite. Students can learn more from a moderate-sized, nondescript, phlegmatic gorger than from a large, fancy species addicted to hunger strikes. In many localities the lowly garter snake is the best species to keep. It eats earthworms, small toads, and frogs with equal avidity, and in winter when these are hard to come by it will usually accept chopped fish or meat, especially if previously trained by having been offered these mixed with earthworms. In early spring ask your students to bring in every garter snake they find, so that you may select several large, gentle individuals with good appetites. A well conditioned garter snake, placed on a newspaper-covered table in the midst of a class, should be oblivious to everything but the handful of night crawlers with which you confront it. One or two large garter snakes can generally consume all the earthworms the average class is energetic enough to dig. A really large specimen is apt to be a female, well along upon the road to motherhood. The late summer birth of her brood, although possibly trying to teachers in adjacent rooms after some of the tiny youngsters have escaped, as they generally do, will provide an excellent demonstration of ovoviviparity and will impress upon the students that garter snakes have large families—up to 78!

The well-populated classroom zoo must have at least two anurans; a toad and a tree frog are the irreducible minimum. The toad should be a large matron of a locally common species, for in toads placidity and girth appear to be correlated. About two years ago one of the members of our herpetological staff at the Carnegie Museum, Miss Dorothy Long, returned from her vacation with an unusually large American toad. "Winnie" soon made herself at home in a folded piece of heavy paper beneath a bookcase and since then she has had the freedom of the laboratory. She gets underfoot only when the pangs of unsatiated appetite or the balmy air of spring make her restless. So far as appetite is concerned she is indubitably gourmand rather than gourmet, for she has obligingly eaten every moving thing that she could pick up with her rapidly flicked tongue, and her record banquet was 152 Mexican bean beetles within an hour. Earthworms and meal worms are her usual fare but salamanders, cicadas, black widows, millipedes, praying mantis, and

AMERICAN TOAD—Its appetite for insects is almost insatiable.

many insects have been eagerly lapped up, and only eight-inch long young snakes have proved too much for her enfolding tongue.

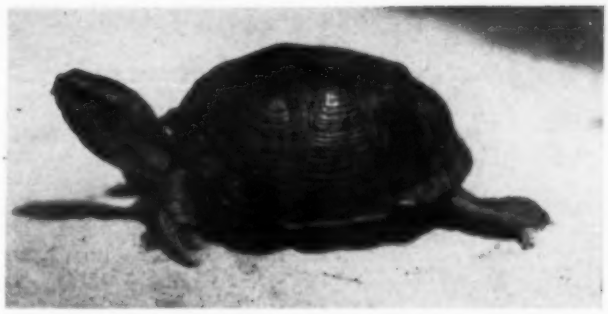
The tree frog may be any species of the genus *Hyla*; in the northern states the gray tree frog, *H. versicolor*, is best, and in the south the green tree frog, *H. cinerea*, is excellent. Tree frogs are famed for their homing ability and after a specimen has become accustomed to captivity it may be allowed to live uncaged among potted plants, from whence it will probably roam to an uncovered aquarium or to the laboratory sink when in need of water. Unlike the toads, tree frogs eat by grasping the food in their jaws, so they soon learn to accept meal worms or other tidbits from forceps or fingers. For variety, however, they should be caged with flies and other soft-bodied insects from time to time and forced to stalk their prey. Captive males of most species call frequently on moist, spring days, and occasionally at other seasons when stimulated by building vibrations from a passing freight or by certain rhythmic sounds. If fed at least once a week and provided with an always moist, moderately cool refuge, a tree frog should live for five to fifteen years in captivity.

To represent the ancient order of turtles I strongly recommend a tough adult rather than a delicate little hatchling. The box turtle is the most usual and perhaps the most dependable turtle pet, but I have a personal fondness for the wood turtle. Frequently, a fasting newcomer may be persuaded to eat by offering it a piece of banana, a fruit greatly relished by many kinds of turtles, or by caging it with a turtle that is feeding readily upon fruits, berries, lettuce, or raw meat.

Eventually every biology teacher is offered a young alligator that has suddenly and properly put an end to teasing by seizing the tormenting finger with 80-odd needle-sharp little teeth. Kept at 70 to 80°F., provided with four inches or more of water and a basking rock or log, such offenders often become docile, feeding twice weekly in warm weather and fasting during the winter. Small alligators are useful for demonstration of tonic immobility following stroking, and they hiss when annoyed and grunt in response to various stimuli, but I have yet to encounter one with real personality.

Lizards are more intelligent than most reptiles, and I recommend them highly as pets for the discerning fancier. In the classroom, it must be admitted, they lack the popular appeal of snakes. They are so active that they are prone to escape, and their requirements vary so greatly that general recommendations are of little value. My own favorite native lizard pets are the hardy skinks, but two other types merit mention because of the frequency with which they reach the classroom.

When a circus comes to town herpetologists' telephones shrill incessantly as young and old, arriving home with anoles tethered to pins, awaken to the realization that they do not know how to care for lizard



BOX TURTLE—Addicted to fruits, especially bananas.

pets. These little tree-climbers, usually from southern states, are often miscalled "chameleons," because they are capable of rapid color change in response to temperature, excitement, or light. They may flourish if released on plant bedecked sun porches or window ledges to stalk flies, insects, and spiders. Unhappily, most captive anoles die of thirst because they have never learned to drink water, and their owners are unware that they are accustomed to lapping droplets sprinkled on leaves.

The Texan horned lizard generally has a far shorter life as a pet than the credulous attribute to it in cornerstones. Unless ants are provided in quantity and both water and sunlight are readily available, captives slowly weaken and die.

The red-spotted newt, although not a spectacular performer, is one of the easiest salamanders to keep in the classroom. The immature, terrestrial red eft will live unobtrusively in a moist terrarium, feeding upon Daphnia, white worms, small earthworms, sowbugs, snails, and spiders, and occasionally posing its orange-red body spectacularly upon a clump of green moss. The green-sided, yellow-bellied adults flourish in balanced aquaria, swimming gracefully among the plants. Both sexes should be kept, for if conditions are satisfactory it may be possible to observe courtship, spermatophore deposition, and egg laying; and, in any event, the specimens may be used to illustrate secondary sexual characters. Except in winter when aquatic newts often fast, white worms, tubifex, small earthworms, or chopped beef, liver, or fish should be fed every other day. Since over-solicitous students can upset a balanced aquarium by dropping in too much food, some teachers remove the newts to small glass dishes for feeding.

I can think of no more appropriate way of ending this brief discussion of herpetological pets than by paying tribute to one of the nicest guests I have ever entertained in my laboratory cages. From 1936 to 1943 the prize pet of my laboratory was a seven-foot indigo, or Florida gopher, snake. Victor, as this blue-black giant was called, made up in immaculate shininess, impressive girth, and docility of manner for his limited I. Q. He would eat almost anything zoological at almost any time, from birds that committed suicide by flying against museum windows to large hunks of beef that

(*Continued on Page 97*)

An Advanced Freshman Course in College Chemistry

• **By Stuart R. Brinkley, Ph.D.** *(Yale University)*
ASSOCIATE PROFESSOR OF CHEMISTRY, YALE UNIVERSITY, NEW HAVEN, CONNECTICUT.

"When we ask what we shall emphasize in high school chemistry to fit our students better for their college courses, college teachers answer us evasively or in too general terms." This has long been the complaint of teachers in secondary schools.

In this helpful paper a noted chemist and teacher lists certain minima that should be achieved in high school. To teachers who feel that they must teach "everything in the textbook" Dr. Brinkley points out that covering too broad an area leads to superficial treatment.

At Yale, students of proved ability and achievement are classified in an advanced course, the content of which is here discussed.

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The content and organization of the first year college course in chemistry should be based on a consideration of the objectives of such courses and also on the previous training of the students. The principal objectives of the first year courses in chemistry are generally considered to be the development of an understanding of the scientific method and its contribution to the intellectual and material advances of modern civilization; an insight into the scientist's view of the nature of matter and its changes; and the knowledge of facts and principles necessary to serve as a foundation for more advanced courses in the subject.

Although primary objectives of college courses in chemistry do not depend on the previous training of the student, the degree to which one may approach their attainment does. It is reasonable to suppose that a student who enters college with some previous training in the subject may go further in a year's course than the student without such training. This expectation may be realized only in the event that the previous training is sufficiently complete and exact on the points covered to serve as a foundation, and the college course is planned so as to capitalize the school preparation.

The development of a more advanced course is complicated by the great variation in content, emphasis, and standards of achievement in different school courses. Courses designed to present a survey of the field of chemistry, with primary emphasis on its practical contributions to present-day civilization, do not afford the foundation necessary for an advanced course. The chemical basis of many modern contributions of science is too complex to be grasped by the student in the elementary course. The attempt to cover too broad an area leads inevitably to superficial treatment.

To serve as background for more advanced courses, the first course should be limited in scope so as to make possible thorough preparation on fundamental principles. Although great differences in opinion among teachers are recognized, nevertheless there are certain fundamental topics that are common to all such courses. The teacher in a following course should be able to assume that the students have a basic knowledge of these topics. The student will have covered many other topics also in his school course; but many of these additional topics are not common to all courses.

Before coming to college the student should have learned, either in his science courses or in his general program, how to study. He should be able to read passages of moderate difficulty requiring the learning of new vocabulary. From his school course in chemistry, he should have acquired the ability to select and incorporate into his thinking the important ideas in a passage. He should be able to solve simple arithmetical problems illustrating principles, so that he understands the significance of the steps involved, not merely gets the right answer. He should understand the requirement of exactness in statement and should recognize the limits of accuracy that are necessary in learning a science. He must appreciate the significance of factual evidence as the basis of scientific knowledge.

The student entering a college course in chemistry that presupposes school preparation in the subject must know the meaning of the symbols and valences of the common elements, and the derivation of formulas from percentage composition and from the valences of the constituent elements. He should be able to use formulas correctly in writing equations for simple reactions, such as the direct union of elements, displacement, and double decomposition. In addition to these vocabulary and language requirements, he should know the distinguishing characteristics of substances and their classification as elements and compounds. He should know the basis for the classification of the elements in related groups and of the compounds in classes of similar substances. He should know what these classifications mean in terms of the behavior of the substances involved. He should also have learned the laws describing the weight relationships in chemical reactions, and their interpretation in terms of the atomic theory. He should have at least an elementary knowledge of the

(Continued on Page 100)

Elementary Statistical Analysis for High Schools

● **By S. E. Torsten Lund, Ph.D.** *(University of Minnesota)*
PROFESSOR OF EDUCATION, UNIVERSITY OF OKLAHOMA, NORMAN, OKLAHOMA.

Should high school mathematics include instruction in the elementary phases of statistical analysis and interpretation? If so, can material be found that is simple enough for pupils to understand and at the same time challenging to their interest?

Answering both questions in the affirmative, Dr. Lund outlines a suitable teaching unit, one that may be varied in difficulty and completeness to fit any grade of junior or senior high school. The unit will be used this Fall for the first time in the Campus School of the University of Oklahoma. Actual classroom use may suggest some changes, but in its present form it should prove to be a stimulating and highly instructive unit.

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A Suggested Unit Based on Air Age Materials

While the Air Age had its beginning nearly fifty years ago, our schools, by and large, have been slow to accept Air Age materials as a legitimate ingredient of the curriculum. Undoubtedly one reason is that our teachers know little or nothing about aviation and related materials. They believe that aviation is such a complex field of knowledge that they cannot be expected to bring it into the classroom. There is some truth in this point of view. However, it must be pointed out that the boys and girls now in our schools must live in a world which has been, and will be, very materially changed due to the new imperatives resulting from the impact of human flight. We must, therefore, attempt to move into the Air Age even though our preparation is limited.

While it is imperative that teacher education institutions assist teachers in gaining some degree of competence in aviation and its implications, the teacher who lacks such preparation and assistance need not despair, for it so happens that today's children are tremendously interested in aviation and have a surprisingly good foundation in much of the informational background necessary to do substantial work in this field. Aviation is, therefore, an almost ideal field in which to develop teaching units, for the units can be worked out by teacher and pupils in a cooperative manner. In the process both the teacher and the pupils can gain competence in this new and fascinating field.

It has long been the conviction of the writer that high school mathematics should include instruction in the elementary phases of statistical analysis and interpretation. However, successful teaching of the elementary concepts of statistical analysis requires material which will challenge the interest of the pupils, and which is simple enough for them to grasp. One of the basic elements of the Air Age, that of air distance, offers material which is entirely suitable for this purpose. It can be set up as a teaching unit with varying levels of completeness and difficulty suitable to any of the grades in the junior or senior high school.

The problem can be stated thus: How much shorter is air distance than highway distance? This appears to be a simple and ridiculously easy question, but if the average citizen is asked to answer, it will soon be apparent that he has only the foggiest understanding of the problem. What is more surprising is that airmen, who ought to know, are unable to give a clear-cut answer. However, it is a question which can be answered by making use of some of the simpler techniques of statistical analysis. While the primary emphasis may be on the mathematical analysis necessary to secure an answer to the question, the possible concomitant learnings are limited only by the ingenuity and imagination of the teacher and the pupils. The following outlined procedure will provide the interested teacher with a starting guide. Experience in carrying out such a unit will suggest modifications.

Problem: How does air distance compare with highway distance?

Materials Needed

Navigation plotters scaled for 8 and 16 miles per inch, or ordinary rulers scaling ⅛ and 1/16 inch.

Set of aeronautical navigation charts. The WAC series of charts is recommended.*

Set of U. S. A. highway maps.

Method of Solving the Problem

Measuring the air and highway distance for a sampling of trips in the U. S. A.

Applying simple statistical techniques to the collected data so as to produce:

1) A frequency distribution
2) A measure of central tendency
3) A measure of dispersion
4) An analysis of adequacy of sampling
5) Etc.

*These charts are prepared by the U. S. Coast and Geodetic Survey. While the common "Sectional" charts (8 miles to the inch) can be used they will be found to be clumsy to handle. The WAC charts are scaled 16 miles to the inch and are more suitable. They cost 25c per chart, and the entire U. S. A. is covered by 37 charts. Old printings of these charts, obsolete for aviation purposes, are available to schools at no cost by writing the U. S. Coast and Geodetic Survey.

Procedure

A few preliminary measurements can be used to develop some safeguards needed in order to secure a truly representative sampling. For instance, air line and highway distance differ to a greater extent in the rugged mountainous sections of the Far West, than in the case of the Midwest, indicating that sampling should cover all sections of the U. S. A. Again, it is obvious that the sampling should include trips of varying distance ranging from possibly 50 miles to 400 or more miles.

If WAC charts are used, each chart should be identified by writing its number on the chart itself, since in order to be used, the margin which carries the identification number must be trimmed away. When properly and accurately trimmed, these charts can be placed together in groups of 2, 4, 6 etc. to provide coverage of a fairly large area of the country. Thumb tack four adjacent charts on a large table or on a wall. Select some town near the central part of the chart combination and use it as the point of departure for sampling that portion of the U. S.

Measure the distance to 8 towns, one each lying N, NE, E, SE, S, SW, W, and NW of the point of departure, using a radius of approximately 50 miles.

Repeat the 8 measurements using a new radius of approximately 100 miles, then of 150, then of 200, and of 250, etc.

Repeat the entire process using 4 different charts to represent another portion of the U. S. A. and continue until approximately 200 measurements have been made.

On a large tally sheet, indicate the name of the town used as the point of departure, and opposite the name of each town used in measuring distance enter the figure indicating air miles, leaving the right half of the tally sheet blank for use in noting the comparable highway distance.

For each of the trips, now count up the highway mileage, using the most direct, all-weather highways and enter the figure opposite the appropriate town on the tally sheet.

Completion of this procedure will provide the class with the raw data needed for the statistical analysis.

Statistical Calculations

For each trip measured, calculate the difference between the air distance and the highway distance; enter the figure obtained in red on the tally sheet.

Convert each "difference" value into per cent of the highway distance; enter the figure in blue on the tally sheet.

Tally the blue figures in the form of a frequency distribution.

Calculate the average. It is suggested that the median be used since it is easily understood as the "middle" value of distance saved by air travel.

Divide the distribution into "quarters" to find out how much variation from the "middle" value is necessary to include the "middle half" of all the trips.

Now repeat the tally of distribution frequencies using, for example, all the East measurements, then all the West, etc. thus securing a number of "small samples." Calculate the median and the interquartile range for each of these to demonstrate fundamental facts of "adequacy of a sampling."

Numerous other statistical manipulations can be performed depending on the interest and capability of the pupils and the time available.

To illustrate the end product of such activity the following table shows the frequency distribution of "per cent saving" of air distance over highway distance for a sampling of 329 distance measurements throughout the U. S. A.

Table 1. Per Cent of Highway Distance Saved by Flying for 329 Trips in the U.S.A.

Per Cent Saved	Number of trips
64-67	1
60-63	0
56-59	0
52-55	0
48-51	4
44-47	2
40-43	9
36-39	8
32-35	10
28-31	32
24-27	39
20-23	55
16-19	68
12-15	46
8-11	27
4- 7	22
0- 3	6

In conclusion it is pointed out that the same set of charts can be used for a variety of other projects involving map study, interpretation of terrain, availability of railroad transportation, availability of airway facilities, etc. In fact, it would appear to be such an excellent piece of teaching material, that a set of WAC charts covering the U.S.A. should be pasted on some available wall in the school, to be used whenever there is need of accurate, large scale maps covering our country. ●

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"The solution of a scientific problem does not close a chapter; it opens new problems. Moreover, advances in one field of science make possible advances in another. The solution of a physical problem throws light upon chemistry, and that in turn, on physiology or on medicine. Until man has no more curiosity and no more wants, his quest for knowledge will persist and the application of that knowledge will continue."

C. E. KENNETH MEES
The Path of Science

Scientists Must Be Human

• **By I. Lynd Esch. Ph.D.** *(University of Southern California)*
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You will read more than once this warning to scientists.

Every paragraph contains striking sentences that tempt us to quote:

"The scientific method . . . is therefore, in our judgment, the most important contribution of science, and at the same time the most dangerous one."

"A theory has only one value, and that is the value of challenge."

"The greatest danger of world destruction lies in the concepts of uncontrolled pragmatism and objectivity."

"The world is at the mercy of the scientist and its only guarantee of safety lies in the humanity of the scientist."

"The world can afford only scientists who are sufficiently human to recognize their responsibility to the Divine."

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There is a story told of a man who was looking at an apartment which was for rent. He had gone through it carefully and was much pleased until he came to the last room. The other rooms were clean and in fine order, but this last room had large dark spots on both ceiling and wall. The would-be tenant inquired about the spots. In reply, the landlord informed him that the previous tenant had been a chemist. "Oh," said the prospective renter, "then those spots are chemicals?" "No," replied the landlord, "they are chemist."

This story simply serves to dramatize the most imperative reason why *Scientists Must Be Human.* The first consideration of any scientific research today must be the human consideration if either science or the scientist is to be preserved. The achieved discoveries of the scientific world are so powerful and of such a nature that the only force which can prevent self-destruction is adequate human motivation. The primitive tribes of Australia used a weapon which was known as the boomerang. Science has multiplied the power of weapons by countless millions of times, but they are still in the essential nature of a boomerang; they may return upon the sender. It is a brave and optimistic soul, indeed, who would assert that already science has not produced its own Frankenstein. Certainly scientific weapons now available need only the spark of degenerate human motivation to ignite them into a world-consuming conflagration. With each new and more powerful invention of the scientific world, new and more profound responsibility is placed upon the shoulders of the scientist.

Science has been a great benefactor of mankind. If we were to ask, "What is the greatest contribution which science has made to the world?", we would get many answers. If we take even a casual glance at modern civilization, we are aware that it rests almost entirely upon the marvels of scientific discovery and invention. Remove the products which science has given to us and we live again the primitive existence of a bygone day. Today most people think of science in terms of atomic energy. That is the latest and most marvelous discovery. But it is no more revolutionary than many other discoveries have been in their day. The ancient scientist, although we would hardly call him such today, who discovered how fire could be made, certainly presented to his fellowmen something quite as revolutionary as did those who developed atomic fission. Let us not forget, too, that steam and electricity have had their day, and that present achievements would never have been possible at all without these former discoveries in proper sequence.

A careful consideration of the history and development of science will lead us to the conclusion that the greatest contribution of science has not been any *thing,* but rather, that it has been a *method.* The *method* is more important than any one *thing,* or series of *things,* because it is by this method that all future discoveries and inventions will be wrought out. The scientific method involves much more than laboratory procedures. It involves, first of all, an attitude of mind. It is an honest, inquiring attitude; an attitude that seeks the truth of the universe. It involves also a procedure of thought and action; a procedure that is logical and practical. The scientific method has been applied to the solution of many and varied problems and has been found to be a very efficient tool. It is therefore, in our judgment, the most important contribution of science, and at the same time the most dangerous one.

Let us examine this method briefly. It has two dominant characteristics. These are pragmatism and objectivity. A scientist in almost any field of research would agree that these two elements are fundamental. They are at one and the same time the pride of the scientist and the heart of his method. The scientist is a practical man. His theories have to be proved. They must be reduced to demonstrable facts. Ethereal suppositions are given no room in his laboratory. A theory has

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Trained Personnel as a National Resource

• **By M. H. Trytten, Ph.D.** *(University of Pittsburgh)*
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The recent war demonstrated how much this country depends on personnel of high competence and advanced training for its defense, its welfare, and its future development. The need for men well trained in science and engineering was portrayed dramatically but, as Dr. Trytten points out, there are several non-scientific areas in which highly skilled workers are also essential.

The distribution of competent young people among the various fields of learning is causing concern. A recent survey by the Bureau of Labor Statistics shows that certain professions need now to recruit actively if an acute shortage is not to occur by 1960, while other callings may be overcrowded.

The information given here will be especially helpful to student advisors.

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Probably no lesson taught by the recent war was more fundamental than that personnel of high competence and advanced training constitutes the nation's most important resource and must be so considered. Scientific personnel is by no means the only type of personnel of high importance to the future well-being of the nation. The problems which will vex and plague us in the future are likely to demand additional numbers of high caliber personnel in such fields as international relations, social science, ethics, and public health here and abroad, to mention only a few. But the demonstration of the lesson was most dramatic in the sciences.

The implications of this lesson, however, present some interesting problems. We have known what to do with national resources of other kinds. Gradually in our nation we have come to understand that we must study them, learn to understand their extent, work to protect our supply and work towards a better utilization of our supply. This has been true of our soil resources, mines, forests and water power, for example. All of these have been accepted by the Federal Government as its responsibility. If then it is true that highly trained manpower is our most important resource, then it follows that the Federal Government must be cognizant of the need for primary concern for our supply of this resource as well.

But in this problem there is a fundamental difference. Resources of the types mentioned are inanimate and not subject to social situations to any great degree. But social situations can affect our supply of trained personnel greatly. To provide the best environment for the growth of an adequate supply of highly trained personnel for the increasingly complex civilization we live in, we need a stable and sound educational structure from the first grade through the top training levels, reasonably stable employment situations and facilities, and opportunities for the growth of such personnel in competence and experience in the pursuit of their specialties. This puts an urgency of a new kind back of our efforts to settle our social problems.

Similarly we need to examine with greater care the influences which arise to govern the distribution of our competent young people into the various fields of training. Our civilization is increasingly complex. Many and various activities requiring highly trained personnel are so fundamentally built into our structure that without them we would suffer severe dislocation. For their continuance a steady supply of competently trained personnel is necessary. A diminution in the supply may well seriously handicap the activity and as a consequence adversely affect the welfare of the nation.

For guidance purposes in our educational system we need more information on opportunities in the various fields requiring advanced training. This information should reflect the growing demands of our society in all fields and the present supply of personnel, not only those in the profession, but those in training.

A recent survey by the Bureau of Labor Statistics, for example, predicts employment in a number of fields by 1960. Admittedly based on incomplete information, it is yet important as being the best estimate currently available.

This report will show that about 65,000 physicians will need to be trained for entry into the profession in the decade 1950-60. This means about 6,500 per year, whereas the medical profession has heretofore trained only approximately 5,000, except for the war time acceleration. In the field of pharmacy in this same decade the demand will be for approximately 40,000 trained people. This again is a step up in training from the present rate of about 3,000 per year to a rate of 4,000 per year. The demand for dentists will be even more striking, in that 53,000 dentists will need to be trained during the same decade, whereas the average rate of training is only 3,200 per year. In the field of nursing the shortage will be so serious that considerable expansion of the training facilities is needed. Similarly, in the field of social work training facilities now available will not be sufficient to meet the demand. In the field of library science there is an estimated need for

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How Scientific Discoveries Are Made

• **By H. S. van Klooster, Ph.D.** *(Groningen University)*
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Significant advances in science are usually the result of long-continued, skilful experimentation in restricted fields, but the scientific discoveries that are unforeseen and unpredictable hold greater dramatic interest for the layman. Some notable "discoveries" that every teacher knows about have never been confirmed, but the claims of the discoverers have not been withdrawn.

The writer of this paper brings to light many interesting details connected with the discoveries of famous scientists. Teachers can use much of this material to brighten their teaching, and to encourage pupils to study the history of science by firing their imaginations.

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The secret, which is also the reward, of all learning, is the passion for the search.
Sir Arthur Quiller-Couch.

Some forty years ago I read an article by Ramsay, the discoverer of the now so familiar rare gases (helium, neon, etc.) on how discoveries are made. About ten years ago, I came across a book by a noted French scientist, Le Chatelier, in which he discusses the same topic under the heading *Discoveries and Inventions.*

According to Ramsay there is a difference between discovery and invention. Webster's dictionary states: "One discovers what existed before but had remained unknown; one invents by forming combinations either entirely unknown or attaining these ends by means unknown." Or to express it differently: An invention is a method for utilizing a discovery. Progress in science is usually ascribed to discoveries, and industrial progress is often thought to be the result of inventions. This is a mistaken and dangerous idea since it deflects many active and intelligent people away from a normal and fruitful occupation towards the elusive pursuit of inventions.

The supposed difference between discovery and invention is often illustrated by the puzzle which Archimedes successfully solved, namely, to find out without injury to a given crown, whether it consisted of silver or of gold. By inventing the method of determining specific gravity, Archimedes discovered that the crown was of gold. Discoverers are usually also inventors, but the reverse is not true. Inventions, however, usually precede discoveries. The elements cesium, rubidium and thallium were discovered following the invention of the spectroscope.

The difference between discovery and invention is at present slight or non-existent. One has only to mention the artificial post-uranium elements, not found in nature, to realize that these are more inventions than discoveries in the sense that Webster uses these terms.

Inventions are patentable, and new chemical compounds are, at present, patentable. Hence one might simply state that inventions, nowadays, are nothing but patentable discoveries.

Returning to the subject of discoveries, let me record, first of all, an experience of Le Chatelier, which shows how discoveries are *not* made. During the first world war the general who was liaison officer between the French Academy of Sciences and the French war office pestered the committee in charge of inventions with repeated requests to find an explosive that was ten times as potent as melinite, then in use in the French army. He went so far as to indicate how this was to be done. All the committee had to do was meet once a week and spend fifteen minutes on the problem. At some

H. LECHATELIER—An uncommon photograph.

propitious moment a flash of genius, no doubt, would escape from the brain of one of the committee members. If not, the assembled members were no true scientists.

In order to make discoveries one must be, first of all, a philosopher, endowed with a curiosity of mind wishing to know more than he sees and hence eager to experiment. Rowland (1848-1901), the foremost American physicist of his time, expressed this strikingly in a letter which he wrote, in 1868, when he was twenty years old:

> "You know that from a child I have been extremely fond of experiments. This liking has gradually grown upon me until it has become part of my nature and it would be folly for me to attempt to give it up and I don't see any reason why I should wish it, unless it be avarice, for I never expect to be a rich man. I intend to devote myself hereafter to science."

As to the value of discoveries made, there are those which make headline news and others that are, at least for the time being, of slight importance, even though they reach the scientific or technical journals. Ramsay in his article makes the following allegory:

> "There are two kinds of fishers: those who fish for sprats and those who angle for salmon. I do not say there are not others, but these two kinds are at the extremes of the fishing world. The fishers for sprats are sure of a large catch or, at least, are sure of catching something; but the fish are small, not particularly attractive as food, and of no great value; they are, however, numerous and easily caught. But the salmon fisher hunts a very different prey; if there is any special quality about a salmon, it is his power of motion and his fickleness of taste; so that the angler, when he casts his line, is by no means sure that a fish is within reach of his cast, nor, if he is, whether he will rise to the fly. If fate is propitious, however, his prize is a great one; his pleasure consists not merely in catching the fish but in struggling with him, possibly for an hour or more; wading after him in alternate hope and fear, hope that his line may stand the strain, fear that it may part, or that some hasty movement may lose him his fish.
>
> 'Most discoverers are like fishers for sprats; they go where they are sure of a reward; but the gain is not great, at least as regards sport. It is much more fun to fish for salmon; but then there is a great chance that the angler has mistaken the place to fish, or that he has used the wrong fly; or that the weather is unfavorable; or that a hundred things, impossible to foresee, will prevent the salmon taking the hook.
>
> 'Salmon are now not nearly so plentiful as they used to be; sprats, perhaps even more numerous. And it requires training and a good eye to know where the salmon lie and in what pool to fish."

Harry Brearly, the originator of stainless steels, expresses the same thought in his autobiography (*Knotted String*, Longmans, Green and Co., New York 1941, p. 120) in the following sentences:

> "There is a great deal of donkey work called research, which calls for the same order of ability as threading colored beads. If there is no excitement in the chase there is not likely to be any reward worth coveting. But if the inquiry stirs the blood and fires the imagination, it will be worthwhile though its value in the market is beneath reckoning."

Another quotation from Brearly's very readable book (p. 137) gives the motives of any researcher in the poet's lines:

> "I am not covetous for gold . . . . . .
> But if it be a sin to covet honor
> I am the most offending soul alive. . . . ."

Great discoveries of the past have been made by successfully challenging and demolishing established axioms. Eric Temple Bell in his latest book, *The Magic of Numbers*, mentions Lobachewsky who discovered (invented) a new kind of geometry by challenging Euclid's axiom of parallels. Copernicus challenged the axiom that the earth is at the center of the solar system. Conant in a recent article on "Understanding Science", (*The American Scientist*, Jan. '47, pp. 33-55) refers to Torricelli and Viviani who eliminated Aristotle's concept that nature abhors a vacuum with the discovery of the well known Torricellian vacuum. Another hoary pronouncement, expressed in Latin by *corpora non agunt nisi liquida*, states that substances do not react except in the liquid state. This saying has often been ascribed to Aristotle, but the translation from the Greek merely says that "liquid substances in particular may form combinations". This ingrained idea has, strange to say, persisted till the beginning of this century. It was the pioneer work of Tammann and his followers which successfully established the reality of "reactions in the solid state". There is only, as far as I know, one book in English that deals with this topic. It was written by an English metallographer, C. H. Desch. It deals mostly with metals and contains more physics than chemistry. To a Swedish chemist J. Arvid Hedvall, of the Polytechnic Institute of Göteborg, belongs the credit of having published the first comprehensive text on the chemistry of solids other than metals. It was published in German and as yet has not been translated into English.

There are many ways in which significant advances in science have been made and in order to cover the subject in a systematic way one can proceed to group them as Le Chatelier did in his book called, *De la Méthode dans les Sciences Expérimentales*, Dunot, Paris, 1936, p. 238, according to their "mechanism", in four categories:

(1) those that are unforeseen and unpredictable,
(2) those that can be predicted,
(3) those that are the result of skilful experimentation, and
(4) those that result from the slow and steady pursuit of some particular branch of science.

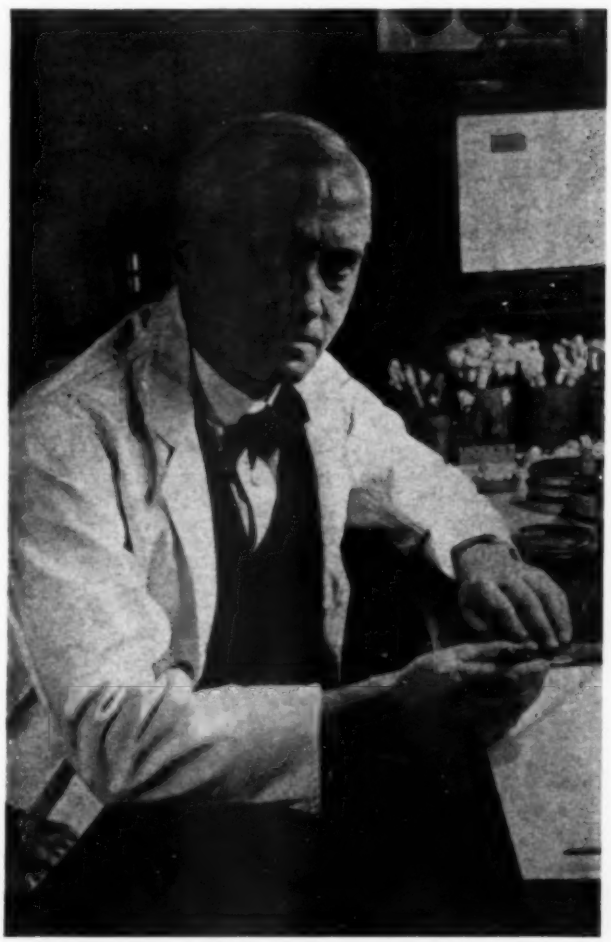
The unforeseen and unpredictable discoveries, the spectacular ones, are, as a rule, of paramount importance to science and to the world at large. These are

the ones that are hoped for and aimed at by most novices in science. Le Chatelier cites the case of one of his classmates, a gifted young man, of independent means, who intended to devote his life to the pursuit of pure science. A brilliant career was predicted by all who knew him. But, alas, being very ambitious, he tackled a too difficult problem which he dropped in disgust after two years of dabbling, whereupon he deserted science to become an honest office holder.

Let me give just one example of a purely accidental, unforeseen discovery, viz., that of penicillin by Sir Alexander Fleming. This English bacteriologist, on the 10th of June, 1929, noting a spot of greenish mold blown in from the outside on one of his culture plates, wrote in his note book:

> "It was astonishing that for some considerable distance around the mold the staphylococcal colonies were undergoing lysis dissolution. The appearance of the plate was such that I thought it should not be neglected. I was sufficiently interested to pursue the subject."

Here then was an opportunity which was not lost and the work was successfully continued. Ten years later Florey and Chain confirmed the observations of Fleming and extended them by studying the effects of penicillin on organisms grown in animals and humans. This work is still going on and has already culminated in the synthesis of this wonder drug. It has been announced by Prof. du Vigneaud and his associates of Cornell Medical College that 10 mg. of synthetic penicillin have been obtained.



SIR ALEXANDER FLEMING

There have been any number of predictable discoveries, some of them amply confirmed and extended and others that have remained isolated and unconfirmed. The profound knowledge of chemistry possessed by Mendeléeff led him to the construction of his periodic table of chemical elements. This was the spark that set in motion the long list of discoveries of new elements the properties and characteristics of which could be predicted in advance. This search has, unfortunately, led to many unconfirmed and hence dubious discoveries. One is reminded of the unverified discovery of carolinium (symbol Cn) by Baskerville in 1901. This was supposed to be a post-uranium element with an atomic weight between 260 and 280. Three years later the same author announced the discovery of the element berzelium (symbol Bz) with the atomic weight 212.7. An element with the same atomic weight, Mendeléeff's predicted eka-cesium, was also discovered in 1931 by Allison and co-workers by means of a specially devised magneto-optic method and was promptly rechristened virginium (symbol Vi). Another unconfirmed discovery by the same authors was Mendeléeff's predicted eka-iodine which they named alabamine (symbol Ab). In the field of the rare earths many unverified discoveries have been made by various investigators. An example is the discovery of illinium by Hopkins and his associates in 1926. About the same time two German chemists Noddack and Tacke announced the discovery of Mendeléeff's eka-manganese which they called masurium. This discovery has, likewise, never been confirmed.

It may be stated at this point that elements corresponding to the blank spaces in Mendeléeff's table, viz., those with atomic numbers 43, 61, 85 and 87 have been obtained recently by atom-smashing experiments. The new names proposed by the discoverers are technetium (symbol Tc) for element of atomic number 43, astatine (symbol At) for element of atomic number 85 and francium (symbol Fr) for element of atomic number 87. Prof. Paneth in the Jan. 4 issue of *Nature* (vol. 159, pp. 8-10, (1947), raises the question why previous investigators have not, in the meantime, withdrawn their statements. Is it because most people, chemists included, hate to lose face?

A prominent predictable discovery was the synthesis of ammonia from its elements. The necessary conditions of pressure, temperature and required catalyst had already been established by Le Chatelier, but when he carried out his experiment, there was a disastrous explosion which nearly killed his assistant and the attempt was abandoned then and there. It was, Le Chatelier admitted, the biggest blunder of his whole career. It

was Fritz Haber who, five years later, got the credit for this discovery.

The celebrated artificial production of diamonds by Moissan was another predictable, though never confirmed, discovery. According to the geologists the minerals produced far below the surface of the earth, in the zone of anamorphism, are those that require heat absorption and contraction of volume for their synthesis. Applied to carbon (or graphite) this meant that high temperature and enormous pressure were needed to transform carbon into diamond. Moissan tried it by the quenching of molten iron in which carbon had been introduced and thereupon announced the production of diamonds. Le Chatelier, in his book, says that even in Moissan's lifetime few scientists took this "discovery" *au sérieux*. However, it still is mentioned in all elementary text books. This fairy tale is even propagated in an advertisement in *Science* by a reputable chemical concern. I wrote to this firm about the matter and received the following reply:

> "It is a fact that the errors which you mention, by repetition, have the value of truth. Probably 999 chemists out of 1000 would give Moissan credit for the things which you state he never did. From the writer's experience with such things it is an impossible task to overcome the published fiction."

Moissan is also credited with the discovery (invention) of the electric furnace whereas, as a matter of fact, this had been used long before Moissan by Siemens. Moissan carried out many spectacular performances which are on a par with such features as the scaling of virgin Alpine peaks. They make good headline news but are of no particular value to the progress of science. What, says Le Chatelier, would become of chemistry if leading chemists focussed their attention on the production of diamonds? Only the exigencies of a life-and-death struggle could bring about such a condition. In the war just ended the Germans put a number of scientists to work on the production of quartz crystals, a scarce article in Germany, yet an extremely valuable asset for war purposes.

Moissan's fame rests securely on the successful accomplishment of the isolation of fluorine and the systematic pursuit of the chemical reactions of this nowadays indispensable element. This was also a predictable discovery. In fact, the name for this element and the method of preparing it had already been suggested by another Frenchman, Ampère, to Sir Humphrey Davy early in the nineteenth century. However, in view of the extreme difficulties that had to be overcome, we might well classify this discovery among those that are the result of skilful experimentation. Moissan's work has proved of lasting value to science and industry. Fluorine, at present commercially available in cylinders containing half a pound of the gas at a pressure of 400 psi, is still the subject of numerous researches, witness the publications on fluorine compounds by Midgley, Booth, Simon and others. That freon (CF_2Cl_2) was "invented" by Midgley, as I read the other day, is, however, a myth. It was first made and described by the Belgian chemist F. Swarts, in 1907, long before Midgley embarked on his search for suitable refrigerants.

Another example of this third group of discoveries is the liquefaction of that most elusive of all gases, helium. It was first accomplished early in this century by Kamerling Onnes in his cryogenic laboratory at Leiden and has led to many remarkable researches which have been summarized in a recent publication by his co-worker and successor Keesom.

Scientific progress is best served by the long-continued pursuit of a particular branch of science by one investigator, ably supported by a group of enthusiastic co-workers. The life-work of such a man approaches in its totality a discovery of eminent significance. Berthelot's work on organic syntheses which took as its starting point pure carbon, is a good example. Ehrlich's work in chemo-therapy culminating in his discovery of salvarsan, the famous 606, is another.

This fourth mechanism for making discoveries is the one that Le Chatelier endorses whole-heartedly. It takes the place of the hit-or-miss methods and the rule-of-thumb operations that so oft prevailed in the past. Le Chatelier mentions an interesting example of "team" work in the making of a startling discovery in the field of metallurgy. Le Chatelier was not only a great chemist but also an active participant in the development of metallurgy. He was the founder and first editor of the *Revue de Métallurgie*. Being greatly impressed with the work of Frederic Winslow Taylor, he was instrumental in bringing out French editions of Taylor's books for which he wrote the prefaces. He himself wrote a book called *Le Taylorisme*, in which he outlines the principles of scientific organization, first propounded by Taylor.

Taylor (1856-1915), a graduate in mechanical engineering from Stevens' Institute, was hired in 1898 by the Bethlehem Steel Company to take charge of their machine shop and, if possible, to increase its output. He associated himself with Maunsel White and others and embarked on a systematic study of the various existing self-hardening steels. Recognizing the superiority of Mushet's tungsten steels, he began a thorough investigation of the effect of variable proportions of tungsten and chromium, finally arriving at a content of about 18% tungsten and 6% chromium. It is related that when a test demonstration was given, the steel selected by Taylor and White as the best of the lot, was the poorest of all in performance. This result in turn led them to a study of hardening and quenching temperatures and finally they made the startling discovery that the chromium-tungsten steels should be quenched or air-cooled from nearly 1300°C in order to acquire maximum cutting efficiency. These achievements which increased machine shop output by more than 500 per

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The State Academy of Science

• **By Pressley L. Crummy, Ph.D.** *(University of Pittsburgh)*
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Is yours one of the thirty-five states that support an academy of science? Do you belong? You should. Do you attend its meetings and participate actively in its affairs? Again—you should.

Workers in the special fields of science need the good fellowship, the stimulation, the increased breadth of scientific interest that active membership in an academy provides.

Dr. Crummy points out these and other important advantages of membership.

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Scientific discovery depends upon investigations and study by individuals, but scientific progress and development depend upon the organized effort of all interested persons. The coordinating and publicizing of discoveries and the stimulating of further investigation require that those who are concerned with the advancement of pure science and the application of those principles to practical problems, shall work together. Now, more than ever before, it is important that the non-scientific layman, too, be made aware of the scientific viewpoint and of the advancements that are being made.

The specialized scientific organizations which are concerned with particular fields of science have done and are doing much to stimulate the study of problems in their own areas. Technical publication is basically important. It is as necessary to the advancement of knowledge as a spade is to the digging of a ditch. However, the coordinating and the publicizing of scientific discoveries require something beyond the work of specialized organizations. Such coordination is possible only through general organizations such as the American Association for the Advancement of Science on a national scale, and the state academies on a smaller scale. These organizations permit the specialists to see what others are doing and to get a new understanding of their own objectives. They are better able to give proper publicity to the discoveries made by the specialists. This publicity is essential to the rapid advancement of knowledge, for the specialist in one particular field of scientific knowledge is a layman in most other fields. Arthur H. Compton[1] points out that "science and technology have helped to make us a society of specialists. But specialists can live only by working for each other."

During the war our vast production was made possible by "briefing" the warplant workers on the importance of their individual jobs in the final success of our total war effort. In somewhat the same way the scientific worker needs to be "briefed" on his place in the general scheme of things. The state academy of science can do this job for the smaller geographic area much more satisfactorily than a nation-wide organization. But for greatest efficiency it must cooperate with other such units and with the national association. Today there are some 35 state academies in the United States. These organizations are doing an outstanding job of promoting all phases of scientific development. Not only do they provide outlets for the independent investigator to tell of his work, but in many instances they also assist such investigators financially.

A very important function of a state academy of science is the stimulation of the interests of young scientists. This goal is attained through a special section called the Junior Academy of Science in which the young scientists feel free to discuss their scientific interests. In Pennsylvania, for example, many high school science clubs are affiliated with the State Junior Academy. Under the sponsorship of an officer of the senior academy the members of science clubs are encouraged to study special projects and to present their work at the annual spring meeting. These meetings are enthusiastically attended and the discussions are lively.

Such meetings serve as important outlets for the enthusiasm of the young scientists. In preparation for the annual meetings some regional meetings are held. Probably more regional meetings should be held in various parts of the state. In fact, some state academies of science, notably Wisconsin, sponsor meetings at several centers each year. In view of today's scarcity of trained scientists it is necessary that every effort be made to find and train those who have an aptitude for scientific study and achievement. The junior academy can and does serve to locate and encourage the development of latent talent. In Tennessee, the state academy of science supplements the findings of the Science Talent Search by giving special attention to contestants who were not selected as winners but whose records and test scores show that they have unusual ability.

Through the academy's student membership there is an opportunity for the active continuation of organized interest in scientific study. While the Pennsylvania Academy does not have a separate section for student members now, there is a possibility that such an organization would be advantageous. Whether or not such an idea is ever carried out, there is ample opportunity for the active participation of younger members. Their findings are as enthusiastically received as are those of the older members.

An interesting and highly successful experiment in

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Our Pupils in the New Climate Created by Science

• **By Morris Meister, Ph.D.** *(Columbia University)*

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PRESIDENT, NATIONAL SCIENCE TEACHERS ASSOCIATION

Wise science teachers will invite their Principals to read this article.

Dr. Meister is a nationally prominent leader among teachers of science in secondary schools. As head of a famous high school of science he has pioneered in building construction, laboratory equipment, curriculum planning, and teaching and administrative techniques. His breadth of training and experience allows him to speak with authority.

Dr. Meister realizes how inadequate instruction in science often is, and he points out the need for more time in classroom and laboratory for leisurely teaching. He considers that the crowning glory of the program of science instruction is the after-school activities which it stimulates, but he realizes that administrative recognition of such activities is difficult to obtain.

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The physical needs of man and society are determined by a group of environmental conditions known as the climate. The air we breathe, the water we drink, the food we eat, the clothes we wear and the kind of shelter we build are all controlled by climate. In the final analysis, the climate of any spot on the earth is determined by the angle of the earth's axis to the plane of its orbit. Let this angle change by as little as one degree and basic transformations occur. Indeed, the coming of the various Ice Ages is sometimes explained as the result of gradual deflection of the earth's axis. It does not require a great flight of the imagination to picture the effect upon the life of a community of a sudden change in the angle of the earth's axis of rotation. Nothing more disruptive to existence can be conceived. If utter destruction does not follow, certainly new orientations are essential. The whole pattern of existence becomes strange and new. Survival now depends upon intelligence and ability to make adjustments. It depends also upon knowledge and understanding. Otherwise man will continue to freeze to death while lying upon a ledge of coal. The whole program of education is profoundly affected.

The Changing Social Climate

It is more than a mere analogy, to say that social climate, too, is subject to change. The fact is that our cultural existence is based upon and stems from our lives as physical beings. Students of human history have often pointed to specific events that have marked the beginning or end of certain trends in civilization. The events can be regarded as axial deflections in the sphere of human thinking; the consequent trends are changed social climates. On a time scale in which the units are centuries, there have been many changes in social climate; yet we possess written records of less than one hundred such units out of the 20,000 that reach back into human history. Acceleration has been fearfully rapid. Social climate is changing at a great pace.

Science Is Deflecting the Axial Angle

The impact of science upon our social climate has seldom been as well described as in George W. Gray's book, *Science At War**. Opening his chapter on "Science and the New World," he says:

> "The future comes. Never in human history has it come with pace so swift and bringing promises so world-sweeping as now. For these violent times are no ordinary struggle between national sovereignties. They are the hammer strokes forging a new world. It must be new, for forces have been set loose which can not be crowded back into the old familiar patterns, forces of human aspiration as well as forces of physical power. It is idle to think of these forces as evil. The future *can* be better than our past—if we have the courage and the intelligence to accept change and adapt ourselves to the new conditions."

When Karl T. Compton was asked on a radio program to outline what the new science climate might bring to mankind, he said:*

> "I look to see a race of Americans made healthier by medical progress and better living conditions. I look to see them gainfully employed in industries now undreamed of or only in the embryo stage. I look to see more wealth distributed, not by taking it away from someone else who has a good share, but by creating it—for that is the proved way of science. I look to see people living in homes of new designs, greater convenience and attractiveness, based on new structural materials and methods, and located in groups planned for effective community life. I look to see great cyclotrons operating as chemical factories instead of as laboratory instruments. I may see great power plants in which the fuel under the boilers need not be replenished in a thousand years. I shall certainly expect to see rain and fog eliminated from the list of hazards to travel by sea or air. These are only a few samples of what America's future looks like to me."

**Science At War*, George W. Gray, Harper & Bros. 1943

Yet, the full force of science upon our social climate must not be measured wholly in terms of technological advances. Its effect upon the spirit of man is just as great. Indeed, physical well-being and spiritual health are but different facets of the life of an individual or of a group. Thus, we can expect that art, music, literature, philosophy, religion will all reflect the changed frame of reference that science has created. Government, politics and the entire web of social arrangements will make use of and be used by science in the new pattern of human relationships.

The Climate of Science Is the Climate of Democracy

While there have been many efforts to link science with democracy, the union has not always been perfect or permanent. Difficulties of definition develop. Rising to confound us is always the fact that totalitarian governments also make much use of science. When, however, we relate science and democracy in a symbiosis rather than as a linkage, we can study their interdependence in a new context. The fact is that the climate of science *is* the climate of democracy. When one grows sick, so does the other. When one grows strong, the other cannot remain weak. Science in this sense does not exist in a totalitarian world, no matter how assiduously and cleverly its technical men operate.

Borrowing from Horace M. Kallen's discussion of *The Scientific Spirit and the Democratic Faith**, we can point to the history of the sciences and show that they are "preeminently the fields of free thought. No idea, no hypothesis, no technique . . . is admitted to a privileged status. None is exempt from competition. . . . None is denied cooperation of its competitors in the tests of validity. None enters the field as a truth revealed . . . beyond the challenge of doubt, beyond the proofs of inquiry. . . . An idea's credentials are not *where* it came from, or *who* thinks it, or *what* it is, but how it is proved or established. . . . Scientific society hence is open society, a democracy of the spirit which anybody may enter who will, and from which only those expel themselves who violate its rule of equal liberty for different views by endeavoring to impose a monopoly for one view on a basis of unearned privilege and not of earned merit."

The same rule obtains in a democratic society "based on the recognition of equal rights of different human beings. . . . The democratic faith is the affirmation of the right to be different . . . equal liberty for the little people with the great, the poor with the rich, the weak with the strong, . . . the minority with the majority. . . . In the world of democratic virtue, as in the world of science, majorities and minorities are associations of individuals joined together on equal terms of constant free cooperative competition and competitive cooperation in the course of which majorities become minorities and minorities become majorities. None holds itself to be established to endure forever unchanged."

**The Scientific Spirit and the Democratic Faith*, Horace M. Kallen, pp. 4, 5, King's Crown Press, 1943

What Science for the Citizen?

We have been trying to establish the unique significance to social welfare of science as a realm of human experience. As such it has not only altered our lives in terms of the basic needs and comforts of physical existence, but in terms of cultural outlook as well. Both as subject matter and as method, science has disturbed the world's "axis of rotation" so that a new social climate is descending upon us at an accelerated pace. The bitter and costly war is over, the forces of democracy have won. Yet the victory seems empty and temporary, unless individuals, groups and nations accept and become attuned to the scientific climate—the essential counterpart of the democratic way of life.

This suggests at once a problem in education. At the risk of appearing to offer still another subject panacea for educational ills, we submit that the social climate of the present and the future requires more and better science instruction for all. Not to give all citizens a better understanding of the part that science and the scientific spirit are playing in the world, is to fail to solve social problems and to create new ones. The citizen who never goes beyond the stage of regarding science as a source of gadgets, magic and miracles is also a potential tool for a dictator. If ninety per cent of all men and women knew more about the workings of the human body than they now do, we would have a healthier society. If ninety per cent of all men and women understood better the interdependence of living things, our natural resources would be better conserved. By the same token, knowledge of the energy concept is related to the solution of our utilities problem; perhaps even the problem of unemployment. The same relationship exists between the problem of housing and a knowledge of the materials in the crust of the earth; between gullibility to propaganda and knowledge of different kinds of communication. This series can be extended indefinitely. While correct understanding is not always a guarantee of desired conduct, one can not deny that it is a *sine qua non* of intelligent behavior in a democracy.

More Science in the Curriculum?

One might offer the dangerously simple solution: Let us teach more science to all children and all grown-ups. At once an army of the opposition flies to the attack. They confront such a proposal with all the glaring evils of present-day science teaching; its abstractness, its lack of appeal to the masses, its frequent divorce from real life problems, its over-logical organization, its separation from social significance, its emphasis upon subject rather than learner, its traditional disciplines, etc. There is enough truth in each of these criticisms to justify asking: What kind of science do you wish all to have? Yet, how can we determine what kind of science to teach until we try teaching some science? The sad truth of the matter is that few school systems have science teaching programs worthy of the name. The program in the elementary schools is

scandalously inadequate. The junior high schools are making the most of a bad situation. So-called "related science courses" in vocational schools do not even aim at the contributions which science can make to education for citizenship. Science teaching in high schools is spotty and meager. Sequential learning is difficult in an over-crowded curriculum. About half of our boys and girls pursue science courses for as much as two years; 37% have only a year of general science; less than 12% of them get three years of science; about three per cent succeed in following a four-year science sequence. At few points in our educational system do we find any great concern for bringing the natural sciences into vital relationship with the social studies or with other real educational school experiences.

We do not know what kind of science to offer in the junior high school to children who have had six years of the right kind of elementary science. Nor do we know just what kind of biology, chemistry and physics would be suited to pupils who had experienced the sequential learning of the preceding nine years. Actually, the course in general science assumes little previous science learning. To a large extent, biology, chemistry and physics develop their respective understandings as if pupils never had had contact with science experiences before.

Adequate attention to science in the curriculum would bring more and more of the material usually taught in senior high schools, down into the junior high school grades, there to displace material that will seek lower levels still. There are few science concepts that involve inherent learning difficulties that can not be overcome by proper methods of teaching. Sequential learning and a planned program will make easy many things that now seem difficult. The fact is that our present grade-placement of science ideas shows a history of displacement downward in some cases from college to elementary school.

We need more time for science teaching, because people must know what they can make science do for them. We cannot rest satisfied with expressions of hope in general terms. The only way to let people know is to organize for them a body of learning experiences and activities from which knowledge and skills can grow and develop. Time is the essence of this process. Time conditions every classroom, every child, and every bit of science teaching, regardless of curriculum, philosophy, method, or text.

But there is a second consideration which lifts this cry for more time out of the quibble for more emphasis in the curriculum. This stems from an examination of the procedures inherent in developing an understanding of science concepts. These concepts can be established only by sequential teaching. There are different levels of understanding. For example, a six-year-old can catch a glimpse of the idea of gravitation which, through the teacher's skillful handling, can in time approach an appreciation of Newton's Law of Motion. Of course, everyone can not attain the level of an Einstein in this respect. Yet, everyone is capable of considerable progress in that direction. Long experience in the classroom indicates that this progress requires time. Skillful teachers of science possess the "know-how" of facilitating the progress from how a magnet behaves, to how the radio works. This development is not simple, yet not impossible; but the sequence does take time. The same can be said for all the "common learnings" in science.

The Need for Time in the Classroom

In the last analysis, the fine phrases of educators must be reduced to learning situations and pupil activities in the classroom. Now, every successful science teacher knows that effective classroom work must, above all, be leisurely. There are many pauses in a good science lesson—pauses filled with silence. These are periods of observation, periods of reflection, periods of time when puzzlement possesses the minds of students. They are intervals during which facts are sifted and weighed in terms of problems to be solved. The teaching tempo is slowed down purposefully, in order that minds can be oriented and prepared for conclusions that are supported by both evidence and logic. Should this procedure be hurried, strange results may follow. Some of the minds go blank, losing the sequential threads that tie thoughts together. Other minds resort to accepting the predigested thoughts of the teacher or text. The conscientious ones will make records in notebooks and then memorize them for reproduction at examination time.

Much of the poor science teaching against which critics have declaimed results from failure to recognize the prime need for leisurely science teaching. In the main, such teaching is a process of *evidence gathering.*

Were we to examine all the different things that teachers and pupils do in a science classroom, we should classify the activities into four groups. First, there are the facts and ideas given to students on authority, either by the teacher or the text. Obviously, a certain amount of authoritarian teaching is inevitable. For example, the pupil is told that stars are distant suns, some of them many times larger than our sun. At elementary levels, one cannot expect the pupil to make this discovery himself, and it is economical to have him accept that statement for the value that it may contribute to other understandings. Secondly, there is a learning situation frequently referred to as a *discussion period.* It is true that many short cuts to learning can come from the pupils' citing of personal experiences which can be compared with those of others. A discussion based upon these comparisons will yield improved understanding. Still a third learning situation can be found in a host of *audio-visual aids* which bring vicarious experiences into the classroom. However, the really vital kind of learning situation, and the one for which science teaching is preeminent, is that of *evidence-gathering.* Thus, the pupil concludes that air exerts a pressure against objects because he has made

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Atomic Energy and the Science Teacher

• **By Melba Phillips, Ph.D.** *(University of California)*
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A thoughtful teacher considers a situation that disturbs many teachers of science. Her well-considered opinions may help clarify the thinking of others.

Significant points: "We science teachers must turn philosophers . . . the impossibility of a monopoly of scientific facts . . . it is not only impossible to keep a truly scientific secret, it does harm to try . . . to have the bulk of research done under Army-Navy auspices is bad for science, bad for the country, even bad, in the long run, for the Army and Navy."

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We have heard a great deal about atomic energy, and how it is related to the future of the world. But how is it related to us professionally, as teachers of science?

Atomic energy has great significance and interest in itself. In addition, it serves to dramatize and sharpen the more general problems facing scientists, present and future, and science teachers as well. As teachers of science we cannot escape responsibilities in this connection that are much wider than that of training future scientists. Our responsibilities extend to the scientific education of the entire citizenry.

The dangers of grave misuse, and unexplored possibilities for good, are not confined to atomic energy. Other fields are potentially almost as dramatic in these respects. The possibilities of bacterial and virus warfare are especially frightening, because they are so insidious. Chemical warfare would undoubtedly be much more potent and horrible now than when it was first exhibited to general view in World War I. On the other hand, atomic power promises untold benefits for mankind, and one would guess that public health and agriculture might reap a rich harvest from advances closely akin to those which make bacterial warfare possible. The products of science may be put either to good uses, or to bad.

Which is chosen hardly depends on science itself. Political and social problems are involved which we shall not consider here. But all scientists and teachers agree, I think, that the right solutions are more likely to be arrived at in a healthy scientific climate. They cannot be found in ignorance, nor carried out except by the support of an intelligent and well informed public. Which brings us straight to the business of education.

How is the science teacher affected by this problem, which is not altogether new, but so much more critical because of the existence of scientific weapons of mass production?

Very simply, in the first place. He is asked more questions. There is an increased interest and curiosity about simple (or complicated) scientific facts. While it is true that the teacher is often confronted with unbelievable amounts of misinformation, and prejudice in favor of such misinformation, this interest is genuine. The fact that the Smyth *Report* was a best seller, and that more popular science books and even pseudo-science books sell widely today, cannot be overlooked.

The enrollment in science courses has generally increased. The war brought science to the public consciousness. There are jobs to be had in science and engineering, and the boys and girls know it. The demand for scientific and technical personnel may be inflated at present and face a decided slump in the near future, but there is a very real shortage. This is due in large part to the interruption of training during the war. It is up to us to do a good job of sound and efficient training to meet the demand.

But we must pay attention to more than the training of future scientists. The citizen of the future, no matter how he earns his living, will be called upon to have more scientific education than in the past. Since this is equally true, or perhaps especially true, for boys and girls who are not going on to college, or certainly not going further in science, it surely means revamping most of our school science at every level, so that the presentation of purely technical detail is not its whole object.

When we examine the reasons for the confusion concerning atomic energy policy in the past year or two, we see that ignorance of the detailed facts of science was not responsible, so much as absence of any wide knowledge of what the role of science should be. We science teachers must turn philosophers, if only in a very narrow sense. We must teach much earlier and more broadly the tenets on which science rests. We tend to forget that our "axioms" are generally unknown.

Some of the subjects on which vast ignorance has been evidenced, even in the halls of Congress, are so commonplace that I hesitate to put them down. One is the kind of people scientists themselves are. Perhaps the lives and times of great scientists of the past could be used to illustrate the fact that they are just people, with courage and imagination, with a great capacity

for hard work, and above all with complete integrity—all this in regard to their own kind of work. Outside the field of their long and intensive training they may or may not be as ignorant and naive as the average citizen, but science is very highly disciplined, and faking it is impossible.

Scientific talent varies among individuals, but it is no respecter of race, creed, color, or nationality. It does demand opportunity for the kind of training mentioned above, and an atmosphere in which science is encouraged. It should be well known that Germany under Hitler completely lost its place as a leading scientific country, long before the outbreak of the war.

Even more obvious than the lack of monopoly of scientific talent is the impossibility of monopoly of scientific facts. These facts are equally available to anyone who has been trained to look for them. They do not belong to their first discoverers. Historically great discoveries (and smaller ones) are rarely if ever made singly, so that it is impossible to "keep" a scientific secret. They do not have to be stolen at all. Every industrial company knows that it is hard enough to keep a trade secret, which is a matter of invention, not discovery, even if all the blueprints are safeguarded. This is because equivalent inventions may be made, although they will in all probability not be identical.

It is not only impossible to keep a truly scientific secret, but it does harm to try; not alone to the progress of science, which demands the freest intercourse of scientific information, but to the welfare of mankind. The creed of science is that knowledge is good, even if there are possibilities of misusing it. Safety does not lie in the ignorance of danger, but in knowledge, so that something can be done about danger. Science and its application themselves produce dangerous things, to be sure, for which safeguards must be devised. But a moratorium on the use of electricity because it is possible for people to be electrocuted is quite absurd.

Just because science is very useful in a war, and has been particularly useful in the last and most bloody war, all too many people think of science primarily as a part of a war machine. A very intelligent woman once remarked to me: "Science has brought us two world wars." What science *is* responsible for is that now there is One World, the parts of the globe which were once far apart are now close together, and the once remote regions are increasingly accessible. It is the business of the science teacher to make this distinction, as well as the scientific subject matter, clear to his pupils.

The illusion that science is for war has in the immediate past been fostered by the almost exclusively, or preponderantly, military support for science. No one would object to the Army and Navy doing their own research, but to have the bulk of research done under Army-Navy auspices is bad for science, bad for the country, even bad, in the long run, for the Army and Navy. The principle of civilian control of policy, so built into our tradition and formally a part of our civil code, is sound from the military as well as the general point of view. Science must be worked at with intelligent but extremely flexible planning. The more freely it is allowed to develop the more abundant are the possible applications of every kind.

For science is really like an iron mine. The output may be used for making swords or surgeons' scalpels, for guns or the multitude of commodities which enhance the comfort of life. Students as well as scientists can appreciate the reply Faraday is said to have made to the Chancellor of the Exchequer who asked about the discovery of electro-magnetic induction "Of what use is it?" "Of what use is a new born babe?" countered the great physicist. In view of the magnitude and importance of the electrical industry, which is based on Faraday's discovery, the other version of the story is equally apt. According to the alternate story the answer was: "Who knows, sir? Some day you may be able to tax it."

All these simple ideas seem such truisms to the scientist that one is, as I indicated before, almost embarrassed to mention them, much less to stress them explicitly in teaching. But in practice we have failed to get them across to our students. Only ignorance, the lack of scientific education in this broad sense, could be responsible for the policy by which military secrecy is imposed on purely scientific matters which are not even remotely of military significance. Some of these matters are quite immediately connected with health, with the fight against cancer and other human ills. The war against disease is actually being hampered, essentially because the role of science is not well understood.

I do not pretend that science teachers have it in their power to change all this, single handed. We are hardly in a position to decide whether science will be used for the promotion of peace and prosperity, or of war and destruction. But we can and must shoulder some part of the responsibility for the present and the future. Our mythical ivory towers have collapsed. It is now of practical importance that we teach what science is and how it grows, as well as what it is about. This will not be easy, and I do not think it will be possible to find a recipe for doing it. But teachers have long since known that education is often a painful process, for themselves as well as their students. They will not shirk this problem, which is a challenge as well as a heavy responsibility. ●

★ ★ ★ ★

"A world that has science needs as never before the inspiration and direction that religion has to offer. Beyond the nature taught by science is the spirit that gives meaning to life."

ARTHUR H. COMPTON
The American Digest
November, 1946.

★ ★ ★ ★

David Starr Jordan

• **By Joseph H. S. Haggin**
ST. THOMAS HIGH SCHOOL, ROCKFORD, ILLINOIS.

This paper was written by a high school student of chemistry. Submitted by his instructor, the Reverend H. A. Wierman, O.S.A., it was the best of the papers received in response to the invitation expressed in our March, 1947, number in connection with an article on "Becoming a Scientist" by Otis W. Caldwell.

The scientific world mourns the recent death of Dr. Caldwell. His passing necessarily brings to a close this series that he had hoped would stimulate students to make library studies and prepare reports on the achievements of great men of science.

●

Every student of natural science, very early in his studies, becomes acquainted with the works of David Starr Jordan and continues to refer to them throughout his career. Dr. Jordan lived a fascinating life of human service which evidences a philosophy that embodies a real science of living. He was a master hand at adapting scientific knowledge to the needs of men, and he revealed much of his secret in furthering human happiness and enriching life.

David Jordan was a true scientist but his contribution to science was neither the discovery of a "new law of the universe" nor the grafting of a new species of plant. His contribution was the classification of knowledge and the formation of standards to guide the twin sciences of botany and zoology. However, in 1888, Jordan did formulate a new law governing the formation of distinct species by isolation or separation. Jordan is given credit for the discovery of the law not because it was unknown until then, but because he was the first to publish the law as such. Jordan's work provided the science of botany, in America, with a tool comparable to that which was placed in the hands of chemistry by the introduction of Mendeleeff's periodic table.

David Jordan was born on a farm near Gainesville, New York, January 19, 1851, of parents descended from old Puritan stock who had migrated from Devon and London. He was gentle natured, and although interested in sports, especially baseball which had just been introduced, he was very studious and mild mannered. He had great respect for his parents, especially his mother who kept the family life pleasant and congenial.

He attended local schools until his seventeenth year, when he took a position teaching a local grammar school. Before his term as teacher had expired he won a scholarship to Cornell University where he studied until 1872. He paid the greater part of his college expenses by assisting in the department of botany. After graduation in 1872 he took a position as professor of Natural Science at Lombard College in Galesburg, Illinois. He resigned this position a year later and went to the island of Penikese to the south of Buzzard's Bay at the heel of Cape Cod, with the new Summer School of Science to study seaweed and fishes, under Professor Agassiz. During this time he became a supporter of Darwin's theories. Between 1873 and 1891 Jordan held teaching positions in various midwestern colleges, and in 1885 was made President of Indiana University. During this time he continued his studies in ichthyology and made a number of trips exploring the flora and fauna of the Gulf, East and West Coasts. In 1883, he made an extensive tour of Europe which included an ascent of the Matterhorn and a "pilgrimage" to the home of Charles Darwin.

On March 10th, 1875, he married Susan Bowen, a former classmate at Penikese. She died in 1885 leaving him to care for their three children. In 1887 he married Jessie L. Knight. They also had three children. Jordan was an indulgent and kindly husband and father.

In 1891, while addressing an audience at a function at the University of Illinois (laying the cornerstone of the new science building) at Urbana, he received an offer of the presidency of the newly founded Leland Stanford Junior University. He accepted this offer despite two objections. As to the first, California was still rife with discordant elements. The second objection was that the new institution was to be "personally conducted", its sole trustee a business man who was moreover active in political life.

Jordan, although optimistic about his future at Stanford, seemed to consider it an experiment and at a dinner held in his honor by the Indianapolis Business Mens Club he said, "I am going away expecting to ride a very high horse. If I come back on foot I shall hope to find you still friendly and hospitable."

Jordan entered upon his task with great fervor. Thousands of applications for teaching positions were received from every part of the country. At the "advice" of Stanford, Jordan disregarded all of these and chose the faculty from among those whom he considered to be most competent. This is significant in view of the fact that Jordan was supposed to be "free from political entanglements". Soon after he had taken over his new position Jordan issued his first official circular, which contained certain guiding principles to be observed.

"The first aim would be the securing of teachers of the highest talent, successful also as original

investigators. Work in applied science was to be carried out side by side with the pure sciences and humanities and was to be equally fostered. Women and men would be admitted on equal terms. Eighteen departments of instruction were to be provided, all with equivalent entrance requirements, accompanied with a large liberty of substitution and election, no fixed curriculum of any sort being contemplated. The unit of faculty organization would be the professorship rather than the department. Each student, therefore, must choose a major professor who should be his adviser, and in whose department he must take enough courses to fulfill certain requirements. As minor subjects or electives, all classes would be open to any student intellectually ready for the work. To secure a bachelor's degree, each candidate would be obliged to satisfy his major professor and to complete enough of other approved work to fill the conventional four years. The degree of A.B. would be given in all technical courses, that of B.S. for work in applied science.

The largest liberty consistent with good work and good order was to be given to the student. Religious services were to be provided in accordance with a clause in the deed gift, which prohibited "sectarian instruction", but required the teaching of the immortality of the soul, the existence of an all-wise and benevolent Creator, and that obedience to His laws is the highest duty of man."

This system of education, then a remarkable change from the usual "forced college course", served to introduce the new idea of progressive education into the United States.

In 1896, after five years as president, Jordan was made chancellor of the university and in 1913 was made president emeritus. In addition to the positions he held at Stanford, Jordan was at different times Commissioner of Fur Seal and Salmon Investigation for Alaska, and International Commissioner of Fisheries.

In 1908, Jordan was made Chief Director of the World Peace Foundation, and from 1910 to 1914 was President of The World's Peace Congress. In 1915 he was named Vice President of the American Peace Society.

In 1912, La Fontaine, a Belgian leader in conciliation (received Nobel Peace Prize in 1913) asked Jordan to write a pamphlet on American ideals to be printed in French and used as a text in schools. La Fontaine argued "America has been built up by emigration; the most energetic and fittest of Europe's sons created the Republic. You must not forget that for you Europe was and should still remain the beloved Motherland. It is for America to liberate Europe from its burdens, its prejudices, its hatreds. It is your highest duty to reconcile. America is the true international people. These alone can transform the earth into a family of nations, a brotherhood of men. Colonization is the work not only of men and capital but of ideas, by example and experiment."

In 1913, Jordan went to Europe to attend several peace conferences that had been arranged. The first was at Ghent where Jordan met representatives from many countries. From Ghent he went to The Hague where he again met representatives of all nations and himself spoke. He noted the feeling of impending war. From The Hague he went to Metz in Alsace-Lorraine (a sore spot). Here he talked to newspapermen whose views ran from strongly French to uncompromising German.

In October 1913, Jordan accepted an invitation from "friedensfreunde" (friends of peace) to a peace conference in Nuremberg.

In November and December of 1913 Jordan toured England and Europe including Germany giving peace speeches. He had more such talks scheduled for the following summer of 1914 but these had to be cancelled.

When World War I broke, Jordan was in England. He stayed on there for some weeks, then returned to the United States. Once again at home he accepted many engagements to speak at peace meetings.

When the United States entered the war all work of the Peace Foundation was discontinued as all such efforts would have been misinterpreted. Jordan, however, continued to give free lectures on the subject of peace. There were difficulties sometimes but he was persistent. Sometime in 1917 he resigned his office in the Peace Society. In January, 1919, Jordan wrote a series of articles in which he stated what he thought ought to be done at the Peace Table of the League of Nations. Jordan was at this time about seventy years old, but he continued to write and pursue his studies almost to the time of his death, which occurred at his home in Palo Alto, September 19, 1931.

Jordan was a very versatile man, being a scientist, educator, executive, poet, and an advocate of world peace through international federation. As a writer he produced on the average a book a year. His manuals of flora and fauna serve even today as the basis for the study of botany, zoology and natural science. He possessed an intense curiosity and a large capacity for learning and worked for the betterment of man his whole life long. ●

★ ★ ★ ★

"In addition, Philadelphia teachers have found that radio can help them to attain certain objectives. Their experience has convinced them that, used with intelligence and imagination, radio can (1) vitalize the work of the classroom; (2) supplement and enrich schoolroom educational experiences; (3) motivate students to further learning; (4) integrate learning of various subject fields; (5) train youngsters in good taste and in discriminating listening."

RUTH WEIR MILLER
The Educational Record
October, 1946.

★ ★ ★ ★

for SEPTEMBER, 1947

NEW BOOKS

The Path of Science

• *By* C. E. KENNETH MEES (with the cooperation of JOHN R. BAKER). New York: John Wiley and Sons, Inc. 1946. Pp. XII + 250. $3.00.

This is an attractive volume of modest size that traces the development of science against the background of the history of society. Both authors are scientists, not historians; consequently the book should be of unusual interest to other scientists, and to professional historians as well. "Scientists [we include teachers of science] are absorbed in their own problems and too often have little time to spare for the study of history, even the history of science."

A brief resumé of the history of man precedes a discussion of the early growth of scientific knowledge and the methods used in developing theories and scientific laws. A general study of early science is followed by brief one-chapter histories of the separate growth of physics, chemistry, and biology. There is a discussion of how new knowledge has been and can be obtained, and of the present organizations engaged in pure scientific research, and in the application of science to industry. The concluding chapter considers the relation of science to society as a whole, and proposals for its wider application in sociological and political fields.

Here is writing with a fresh point of view that stimulates thought. Instructors will find in it quiet inspiration and much good background material for their teaching.

H.C.M.

Handbook of Microscopic Characteristics of Tissues and Organs

• *By* KARL A. STILES, M.S., Ph.D. (Michigan State College). The Blakiston Company, Philadelphia. 1946. x + 214 pp. $1.75.

This book can be an invaluable aid to both student and instructor. It contains twenty-one chapters with descriptive summary charts of epithelial tissues; human blood; the digestive system; the respiratory system; etc. There are several pages of good microscopic image-pictures showing some of the more important tissue characteristics. The drawings are well correlated with the descriptive phrases, enabling the student to fix firmly in mind the more prominent features of the histological sections. The manual can be used as a laboratory guide or as a supplement to the regular textbook of histology, anatomy or pathology.

The matter is printed on one side of the page only, allowing the student to use the blank pages for his own drawings.

T. M. Brody

A Yanqui In Patagonia

• *By* BAILEY WILLIS. Stanford University, Cal., Stanford University Press. 1947. Pp. x + 152. $3.00.

In this book are mingled autobiography, history, science, politics and quiet humor. The Yanqui, Bailey Willis, professor of geology, emeritus, at Stanford University, first describes his work for the United States Geological Survey and his search for iron and coal lands in our Northwest in the period following the Civil War. He introduces you to Indians, lumberjacks, geologists, soldiers, prospectors,—some of them rather rough characters.

The greater part of the book is devoted to the author's later experiences working for the Argentine government. He helped find artesian water for the railroads, surveyed railroad locations in the Andes, and planned the location of dams, reservoirs, natural parks and cities. He tells of the early history of the peoples he encountered and discusses the geological features of the places he visited. His experiences in Argentine politics will be readily understood and appreciated by readers in the United States.

This book is pleasant and stimulating reading.

R.M.F.

Practical Emulsions

• *By* H. BENNETT, Second Edition. Brooklyn, N. Y. Chemical Publishing Co., Inc. 1947. Pp. xvi + 568. $8.50.

This is a second, carefully revised and enlarged edition of the first book published that dealt with emulsions primarily from the manufacturing point of view. Theory is discussed briefly. Emphasis is on the practical, not the academic.

In general, the plan of the first edition has been retained. Additional matter includes the use of soaps, lecithin, and pectin as emulsifiers, and the applications of emulsions in the synthetic rubber, leather, polishes, cosmetics, paints, dye and foods industries. Stability, methods of emulsification, and mechanical equipment are considered. There is an abundance of formulas, including a number not found in the first edition.

H.C.M.

The Writer-Speaker Handbook

• *By* BETHEL GILLIAM, Sandusky, Ohio. Handbook Publishers, Inc. 1947. Pp. viii + 174. $2.50.

This handbook has nothing to do with science; but every science teacher who studies it assiduously and puts into practice what he learns will be a better teacher because he will be able to express his thoughts clearly,

effectively, and grammatically. Most of the material the reader already knows, or perhaps once knew and forgot. This well-arranged handbook is a good reminder. It is designed as a self help, a teaching aid, and a ready reference.

Parts of speech, punctuation, capitalization, paragraphing, syllabication, and letter writing are studied. There are short sections on the compilation of a bibliography, public speaking, and vocabulary building. A useful index is included. *R.M.F.*

Concise Chemical and Technical Dictionary

• *Edited by* H. BENNETT. Brooklyn, N. Y. Chemical Publishing Co., Inc. 1947. Pp. xxxix + 1055. $10.00.

This book will be convenient and useful for quick reference in any technical or general library. It will be used by librarians, students, salesmen, and manufacturers, as well as by chemists, pharmacists, physicians and metallurgists. It contains some 50,000 definitions dealing with chemistry, many of the other sciences, and technology. The definitions are given in concise, compact form, sometimes even too briefly, although extended definitions and descriptions cannot be expected in a book of this size. The chemical names, semi-structural formulas, molecular weights, synonyms, and physical properties of thousands of compounds are listed. A large number of trade names for proprietary products are given. There is a key to the pronunciation of chemical words, and sections on organic nomenclature, organic ring systems, and indicators. Many tables are included. *H.C.M.*

Chemical Specialties

• A Symposium, compiled by H. BENNETT. Brooklyn, N. Y., Chemical Publishing Co., Inc. 1946. Pp. xiv + 826. $12.50.

This book will be useful to non-technically trained persons who desire to prepare their own chemical specialties on a moderate scale, and to those who intend to make a business of such special products. An explanation of elementary chemical terms precedes a discussion of raw materials, processing procedures, and mechanical equipment. Numerous formulas are given for the manufacture of paints and lacquers, cosmetics, polishes, soaps, food-products, inks, adhesives, insecticides, etc.

Products must be sold; so information is given concerning financing and marketing chemical specialties, record keeping, patent laws, Food and Drug Administration laws and regulations, and many other phases that might trouble the beginner in the field. Sources of raw material and equipment, methods of testing, storing, packing and shipping are described. The equipment needed for a small specialty business is described.

Charles H. Becker

Government Publications

• *Reviewed by* DR. PHILIP G. JOHNSON, Specialist for Science, U.S. Office of Education, Washington, D. C.

Oman, P. W. and Cushman, Arthur D., *Collection and Preservation of Insects.* Miscellaneous Publication No. 601, USDA. 42 pages, 1946. Superintendent of Documents, 15 cents.

This publication gives information on collecting, preserving, handling, mounting, and labeling insect specimens, on subsequent care of collections, and on recognition of the general insect groups, or orders. Suggestions concerning how to make some equipment are given together with comments about rearing insects. The bulletin would be useful to teachers at elementary school levels and to both teachers and pupils in secondary schools.

Furry, Margaret S. and Viemont, Bess M., *Home Dyeing with Natural Dyes.* Miscellaneous Publication No. 230, USDA. 36 pages, 1935. Superintendent of Documents, 10 cents.

Discusses dye standards of fastness, desirable color combinations, equipment for dyeing and procedures. About 65 natural dye materials were tested and are reported in this publicatoin. Useful natural dyes are reported with instructions for treating the fabrics and recipes for dye materials and extracts. Suggests how other dye materials may be tested. Especially useful in the encouragement of home crafts.

Garver, Harry L., *Safe Water for the Farm.* Farmers' Bulletin No. 1978, USDA. (Supersedes Farmers' Bulletin No. 1448,) 46 pages, 1946. Superintendent of Documents, 15 cents.

This bulletin supplies information concerning the sanitary and engineering principles to be observed in providing safe fresh water for rural homes. Topics discussed include sources of water, types of wells and pumps with advantages and disadvantages, and treatment of water, including removal of iron and other minerals. Construction of wells and water storage facilities are discussed in useful detail, including places for fire protection and small plot irrigation. This publication would provide useful information for teachers and pupils and would suggest projects for interested students.

Deetz, Charles H., *Cartography*—A Review and Guide for the Construction and Use of Maps and Charts. Special Publication No. 205 (Second Edition), USDC, Coast and Geodetic Survey. 85 pages, 1943. Superintendent of Documents, 65 cents.

A careful presentation of map making, including historical development, classification and analysis, compilation of materials, map projections, defining directions, construction techniques, and illustrations. This would be a useful reference for secondary school teachers, and it would also prove helpful to students who wished to study the development of maps.

McKee, Roland, *Summer Crops for Green Manure and Soil Improvement.* Farmers' Bulletin No. 1750, USDA. 16 pages, 1947.

This bulletin discusses the crops commonly used and how such crops may be used most effectively in a soil improvement program. Problems such as inoculation, use of fertilizer, treatment of seed, and seeding are discussed. The various crops suitable for green manure are discussed, including the value of weeds for soil improvement. This bulletin will meet a need in the study of conservation in secondary schools.

Mulford, Furman L., *Roses for the Home.* Farmers' Bulletin No. 750, USDA. 34 pages, revised, 1932.

This bulletin discusses general culture, kinds of roses and the locations and conditions suitable for their growth, care of roses, including instructions for pruning, protection, spray and cultivation. While newer varieties are not discussed and new sprays are not included, yet the basic information about rose propagation and care is still useful.

"More high school graduates showing scientific promise must be encouraged to take advanced college training"—ALAN VALENTINE, President
The University of Rochester

Unfortunately, many high school graduates of exceptional scientific ability are forced to choose a job. Financial requisites set up too great a barrier. According to Dr. Bush's study*, it takes 1000 fifth-grade pupils to make 72 college graduates.

If our war-depleted supply of scientific manpower is to be replenished, we've got to provide more substantial assistance to a greater number of high school graduates who qualify for college scientific work.

We must aggressively support the various governmental programs now in effect or under consideration, which include science scholarships.

We should promote and help formulate an increasing number of science scholarship programs in private industry.

We must make every effort to increase America's force of scientific personnel.

**Science: The Endless Frontier*

AMERICA NEEDS MORE SCIENTISTS

BAUSCH & LOMB
OPTICAL COMPANY ROCHESTER 2, N.Y.

THE FUTURE OF AMERICA DEPENDS ON SCIENTIFIC LEADERSHIP

Our Pupils

(*Continued from Page 88*)

a can collapse by removing the air inside of it with a pump. He knows that water contains dissolved air because he has immersed a goldfish for a short interval in cold boiled water, to find that the fish needs the dissolved air in order to live. He understands that rapidly evaporating liquids can make objects cold, because he has moistened his hand first with water, then with alcohol, then with carbona. Obviously, the process of evidence-gathering takes far more time than authoritative teaching or teaching by means of discussion periods, or teaching through audio-visual aids. Time is the essence of teaching by evidence-gathering, and evidence-gathering has in it the chief contribution of science to the education of the child.

The Need for Time in the Laboratory

Individualized laboratory work has not made progress in recent years. As a matter of fact, there has been a retrogression. New buildings have included progressively less space for this phase of science teaching. Existing laboratories have been used less and less by science teachers. Reports from various parts of the country indicate that individualized laboratory work has been altogether omitted. This is a serious matter. It is especially serious in an atomic age which must rely upon schools for most of the general education of its citizens. We can afford to lose much of the subject matter and content now present in science text books and syllabi. We cannot afford to lose the experimental approach in solving problems. Only in and through the laboratory can we develop in individuals that desirable attitude which tends to base belief and conviction upon an evidence-gathering process. When our non-science teaching colleagues seek means for integration in the curriculum, they rarely have in mind specific science subject matter. They almost always turn to science for examples of critical thinking based upon fact and experiment. If, then, we abandon individualized laboratory work, we shall succeed in cutting the heart out of the contribution which science can make to general education.

Let us bear in mind, however, that laboratory equipment and lecture table demonstrations not only cost money but require somebody's time after arriving in the school. The equipment must be ordered, inventoried, stored, arranged for use, repaired, and stored away again in good order for future use. All this takes time —whose time? School administrators and Boards of Education expect of the science teacher the same teaching load as is expected of other teachers. Is it any wonder, then, that science teachers are reluctant to develop individualized laboratory work? Most of them have all they can do in getting the demonstrations ready. Even this is a drain upon the teacher's time which is hard to keep up with.

The Need for Time for After-School Activities

The crowning glory of the program of science instruction is the rich program of outgrowth activities to which it leads. The science teacher knows he is successful and gets his rich professional reward when pupils come crowding up to his demonstration table with suggestions and ideas for further experimentation. The teacher has kindled these sparks and they must be fanned into flame. Hence, he organizes science clubs or conducts field trips or arranges science exhibits, fairs and congresses. These after-school activities have become so widespread that they are accepted as a symptom of good science teaching. The growth of the Junior Science Academies and the Science Club movement are tokens of the regard in which these extra-curricular activities are held by educators, scientists, students, teachers and parents; but they are decidedly time-consuming. There seems to be no limit to the call upon a teacher's time which even a single class of thirty pupils can make. Admittedly, there are clubs and after-school activities in all subjects, but the science teacher is doubly taxed in this connection. Unlike the sponsor of a literary club or a social studies forum, the science club sponsor must concern himself once again with materials, equipment, and their care. The fact that there are willing and enthusiastic youngsters to lend a hand, merely adds another administrative burden requiring time for planning and execution. Even the athletic coach does not have the same nervous strain as the science club sponsor, who is constantly dealing with apparatus that goes wrong, chemicals that can injure, electricity that can shock, and burners that can set fire to property.

The science teacher has a special obligation, especially in this post-war period, to cultivate science talent among our youth. Many profound students of the social, economic, and political scene have repeatedly pointed to the crying need for the training of scientific and technological competence, if our country is not to be left behind. We know how sadly depleted is our supply of scientists and engineers. Our reconversion to peacetime pursuits and the utilization of new knowledge which has come as a by-product of war, depend primarily upon men and women with talent and training in pure and applied science. To meet this crying need calls for still more time for science teaching and from the science teacher. Never before in our history have we needed a more intensive search for science talent and a program of science instruction especially designed for this segment of our youth. By dint of pioneering and voluntary service, science teachers have developed techniques of extra-curricular activity. There is general recognition that the educational worth of these activities often overshadows what goes on in the classroom.

Re-Defining the Teaching Load

The most critical problem in this area is to gain administrative recognition for the sponsoring of science clubs and activities related to them. The teaching load

of the science teacher must be so adjusted that he can find time and energy for these tasks. Unfortunately, the public is not yet awakened to the need for such quality service, to the point where educational budgets will provide for the time and the special training called for by science club and related extra-curricular activities. An analysis of any educational budget will show that the only yardstick of teacher service is in terms of how many times that teacher meets classes every day of the week. This teaching load is usually so exacting that little energy is left for the kind of dramatic, real-life activities which the science classroom stimulates among girls and boys. Every Board of Education, every Superintendent, every Principal wants extra-curricular activity and frequently demands it. But, no one seems willing to pay for it on the same basis as we do for work in the classroom with large groups. Surely, the modern trend in business and industry is in the direction of limitation of the time factor for services rendered. The professional worker need not sacrifice any aspect of the dignity of his services through demanding more adequate budgetary recognition.

In short, if we are to prepare pupils for the new world, we must have more time for science teaching by men and women who are adequately paid and who work under conditions that make possible professional service and professional growth. ●

Reptiles

(Continued from Page 75)

I purchased from butchers who always looked at me askance when I requested dog meat for a snake. Victor's real preference was for food frequently and in quantity, but if he had any specific preference it was for snakes. Although we never offered him a poisonous snake, upon which his kind feeds readily, he proved on numerous occasions that large harmless snakes, including king snakes, were powerless to resist his attack. Ordinarily docile, indigo snakes have too powerful a bite to be kept as classroom pets for young children, and even Victor misbehaved once. A young snake fancier played with some garter snakes, and then, without washing their odor from his hands, opened Victor's cage when my back was turned. Although I disengaged Victor at once, a lacerated hand taught the boy the wisdom of washing food odors from the hands before handling any pet snake. One autumn I returned from a trip to find the following note upon my desk: "On the morning of Wednesday, September 1, 1943, death—as it must to all snakes—came to VICTORINE, long known as VICTOR, the pride and joy of the Carnegie Museum Herpetology Department." ●

★ ★ ★ ★

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or Mastery?

Are some of your beginners baffled by chemical hieroglyphics? Or do they really comprehend the language of symbols and subscripts?

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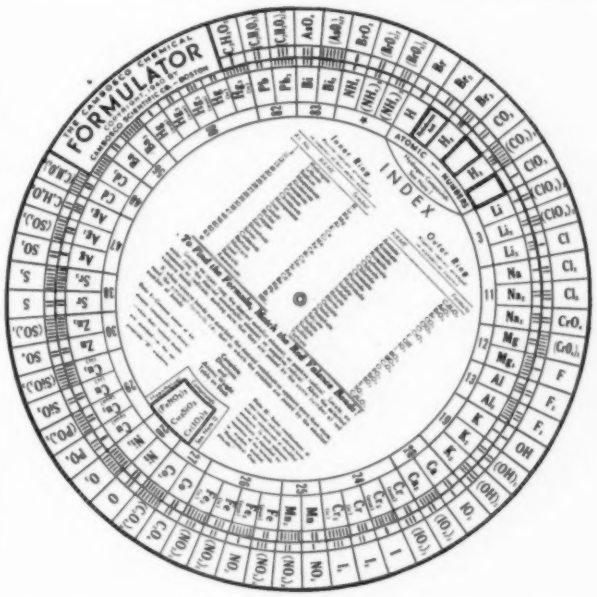

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Enzymes

(*Continued from Page 70*)

What Do Enzymes Look Like?

Most enzymes are colorless and when dry are white or faintly yellowish powders. Some enzymes are definitely yellow, others are pale blue and others are nearly black. When in pure condition most enzymes are injured by drying.

Chemically, enzymes are proteins and belong to the same class of substances as gelatin, egg albumin, wool, silk and hair. Lean meat is largely protein, but it must be remembered that lean meat contains about 75 per cent of water. Enzymes, as well as other proteins, are highly complex and have huge molecules. The elements which are present are always carbon, hydrogen, nitrogen, oxygen and sulfur. Other elements which may occur are iron, phosphorus, copper and zinc.

How Can One Test for an Enzyme?

One tests for the action of an enzyme rather than for the enzyme itself. The simplest way is to cut an apple or a raw potato in halves. After about 30 minutes, the cut surfaces will be seen to have turned brown. In this instance the enzyme tyrosinase has used atmospheric oxygen to oxidize some of the tyrosine in the potato. The first product formed is the reddish hallochrome. Later the hallochrome changes to the brown melanin. Another way to test for an enzyme is to boil some potato starch with a little water, forming a starch jelly. After cooling this jelly, one adds a drop of saliva. The jelly will liquefy, since the enzyme of saliva, salivary amylase, digests the starch forming malt sugar. A third simple way of testing for an enzyme is to add some household hydrogen peroxide to a bleeding cut. Blood contains the enzyme catalase and this will decompose the hydrogen peroxide and form foam. Here the products are water and gaseous oxygen.

The Effectiveness of Enzymes

Enzymes are extremely effective. Since the enzyme brings about a chemical reaction without being used up in the process, it can be understood that a very small quantity of enzyme, if given sufficient time, can ultimately cause a great amount of chemical change. It has been calculated that one molecule of the enzyme catalase from cow liver will decompose 5,000,000 molecules of hydrogen peroxide per minute at zero degrees Centigrade.

The Relationship of Enzymes to Vitamins

While all enzymes are proteins, a certain class, the oxidizing enzymes, are composed of protein united with other compounds. It has been shown that animals can always synthesize the protein parts of enzymes, but that in certain instances they cannot synthesize these other compounds but are obliged to eat them in their food. These other compounds are the vitamins. Thus, we eat vitamins in order to synthesize oxidizing enzymes.

Autolytic Enzymes

After an animal dies some of the enzymes in the body get out of control and digest the tissues. This process is called "autolysis." It is of practical value for the ripening of meat, since it makes meat tender. In the frozen food industry, enzymes sometimes cause trouble by causing the frozen foods to darken and to deteriorate generally. This deterioration can be largely prevented by blanching the foods in boiling water before freezing. The action of the boiling water is to destroy the enzymes.

Enzymes as Agents of Destruction

Enzymes are used as poisons by venomous snakes, bees and scorpions. Venom is simply a concentrated solution of enzymes. When this solution is injected under the skin, or into the flesh, the enzymes immediately begin to disintegrate the tissues, thus destroying them. One of the enzymes, lecithinase A, destroys nervous tissue. Another enzyme, hyaluronidase, dissolves pathways through the tissues, which allows the venom to spread. However, hyaluronidase does not always play the role of an evil angel. It plays an important part in the fertilization of the mammalian egg. Its function is to digest away cementing material that holds together cells surrounding the ovum, thus allowing the male element to reach the ovum.

The Way Poisons Act

Now that we know what enzymes occur in living things and the properties these enzymes possess, it has become possible in a number of cases to explain exactly why certain substances are poisonous. In bygone days, it was explained that a substance was poisonous because it was its nature to be poisonous. Today we can say that sodium fluoride causes death because it inhibits the action of the enzyme enolase, necessary for breaking sugar down to water and carbon dioxide with simultaneous production of energy and heat. Hydrocyanic acid causes death because it paralyzes several oxidizing enzymes.

The Employment of Enzymes in Industry

For hundreds of years, enzymes have been employed in industry. The enzymes are never used in pure condition and often are present in living yeasts, bacteria, or molds. The brewer employs malted barley to convert starch to malt sugar. Here the effective agent is the enzyme amylase. After this has occurred, the brewer adds yeast cells which ferment the malt sugar to alcohol and carbon dioxide. The fermentation is carried on by a group of enzymes known by the collective name of "zymase." The tanner uses the enzyme trypsin to prepare hides for tanning. Here the action of the trypsin is to dissolve and digest away a part of the hide, elastin, leaving another part, collagen. It is the collagen which when combined with tannic acid forms leather. In South America, Indian girls chew cassava roots and then spit the material out on pieces of bark. Here the starch in the roots is acted on by an enzyme

in saliva, amylase, and is digested to form malt sugar. Later wild yeast cells fall into the material and ferment a part of the sugar to alcohol. Ultimately the material is eaten. Old women are not allowed to prepare this food, since it is said that they spoil its flavor.

The American housewife uses junket tablets to make junket. Here the enzyme is rennet, obtained from the fourth stomach of the calf. Rennet is used in large quantities to manufacture cheese. Its action is to convert casein of milk to paracasein, which separates out as a curd. Other enzymic or fermentative processes prepare vinegar, glycerine, citric acid and many other products.

The Increasing Importance of Enzymes

Only 20 years ago, the role of enzymes in life was not well understood and their importance was hardly realized. Today we know that they and their actions are the key to the study of living things and almost all phenomena connected with life. ●

Radioisotopes

(Continued from Page 72)

and there is a definite possibility of getting large numbers of monochromatic neutrons from the pile. This idea seems to be very intriguing, for if sufficient quantities of monochromatic neutrons are available it might be possible to induce reactions which could be very accurately controlled.

Likewise, it may be possible to use intense radiation such as is available from a nuclear reactor for the polymerization of organic compounds. It is proposed to study whether polymerization can be induced under the influence of radiation. At the present time the economics do not look promising for industrial use, but perhaps much new fundamental information can be obtained. Certain compounds will not polymerize under existing conditions; for example, allyl alcohol, allyl chloride and the like. Can they be activated under an intense radiation?

A very practical use of radioactive materials is to ionize the air near moving machinery, particularly near belts, so that static can be eliminated. This static, as you know, constitutes a serious hazard where dust from grain and other organic materials or combustible vapors are present.

The preserving of food from bacterial decay is a problem of great importance. The intense radiation from fission products might be used to destroy bacteria in foods, thus preserving them for long periods. This is a problem which is being worked on.

I hope that these suggestions point out some of the possibilities in chemistry and chemical engineering that these amazing isotopes offer. In principle their use is quite simple, but in practice the achievement of maximum sensitivity and exact measurements requires con-

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siderable training, and as with other research tools, a skilled laboratory technique has to be developed. It is essential that safe health protection from radiation and radioactivity be employed. During the war hundreds of people were trained in this field and acquired the ability to use tracers safely and precisely. Many of our universities, realizing the importance of this new tool, are offering training in its use, and other universities will be doing so shortly if sufficient interest is shown.

A research group completely inexperienced in this field cannot expect to rush into it and obtain worthwhile results immediately, but for progressive groups there is little need for long delay in taking advantage of one of the most important research aids ever developed. ●

Freshman Course

(*Continued from Page 76*)

theories dealing with atomic structure and ionization and be able to apply the principles involved to simple chemical reactions. In addition he must have learned enough factual material to serve as the basis for the rational development of principles.

For many years, it has been the practice in this university to classify, in an advanced course, students with superior records in school chemistry. However, many of the students who have had school chemistry are not adequately prepared to profit by an advanced program. The assignment to the advanced course is based on the school record of the student, both in chemistry and in related courses, the results of aptitude and achievement tests, such as those set by the College Entrance Examination Board, and the field of interest indicated by the student. Our experience indicates that students who do not rank above the average in these tests are not adequately prepared for the more advanced course.

In the course for students with superior ability and achievement, we have found it practicable not only to cover more ground than in the elementary courses, but also to go more deeply into the scientific development of the topics covered. Four or five weeks are devoted to review of fundamental principles. Aside from the specific objective of review, this period provides a unified basis for the work of the course. Emphasis is placed on understanding, not merely factual knowledge. The development of important principles and theories, and the verification and modification of theory in the light of additional data are stressed. In this manner, an understanding of the relationships between specific data, laws, and theories is established so that they may be applied consistently.

During this preliminary review period, knowledge on the part of the student is assumed concerning the topics mentioned in a preceding paragraph. Little class time is spent in the discussion of these elementary phases of the subject.

Theories dealing with atomic structure are now developed with a brief consideration of historical and experimental background. These serve as the basis for an understanding of the nature of the chemical bond, the reactions of the chemical elements and their classification according to the Periodic System, and the activity relationships of the elements in a family. They are applied also in the study of ionization, acidity and basicity relationships in general, and oxidation-reduction.

The study of the elements is based on position in the Periodic Table. Acids are studied as classes of substances, not according to the particular nonmetal they contain. Similar treatment emphasizes the nature of the hydroxides of the metals and of the various classes of salts. The arrangement and development of the material throughout the course is intended to emphasize generalizations dealing with the behavior of the substances, and the rational interpretation in terms of theoretical aspects. In this way, we believe the student may acquire an understanding of the nature of chemical reactions. This we consider more important than unrelated and unexplained information likely soon to be forgotten.

The laboratory work in this course, three hours per week in the first term and six in the second, is qualitative analysis. This is carried out by semimicro procedures; and, throughout, the principles dealing with ionic phenomena are stressed. The majority of the students in this course continue in further work in the subject. Other courses are offered for the students who have had no previous courses in the subject, for the student whose preparation is not adequate for the advanced course, and for students whose primary interests are in the humanities. ●

Trained Personnel

(*Continued from Page 80*)

70,000 trained librarians in 1960, whereas only 30,000 were employed in 1946. In view of attrition, this will mean that 62,000 additional librarians will need to be trained in the same decade.

The newer professions, such as medical laboratory technology, x-ray technology, dental hygiene, physical therapy, etc., are expanding very rapidly and indicated needs are for many more than present training facilities can produce. In some of the older professions, however, there is an indication of oversupply. This is apparently particularly true of the law, where the indications are that there will be an oversupply of lawyers by 1960.

In the field of the sciences quantitative predications are much more uncertain in view of the fact that the expansion of research facilities in the United States is at a wholly unprecedented rate. From information gathered by the President's Scientific Research Board it

seems clear that research is being financed at the present time at a rate several times that of 1940. This, of course, indicates a severe shortage at the present time in most sciences and in the research aspects of engineering. Predictions in this field must be based on considerations somewhat different from those employed in calculating shortages in these other fields. Nevertheless, it seems a fair prediction now that the shortages in these fields will not have been alleviated by 1960.

It is evident from a consideration of these facts that many of the most important professions in the country will need to recruit actively to secure the attention of highly qualified youth. Some of these programs will undoubtedly be subsidized by strong scholarship programs. It appears, therefore, that competition for the young people of real ability will be an increasing characteristic of the future. There is need for a basic and fundamental study of this problem, so that programs in the various fields aiming to secure recruits can be intelligently devised. Without such consideration, it seems very likely that important areas will be denied a suitable supply of competent candidates and the national welfare will suffer accordingly. ●

Scientific Discoveries

(*Continued from Page 84*)

cent were the result of *systematic scientific research.* It is of interest to note that Taylor and White were unable to secure patents on any of the steels they developed in their researches, probably because they stated *too clearly* what they had done so that it was possible for competitors to apply modifications of their procedure which also produced comparable results. It takes lawyers to include in the patent claims operations not planned nor carried out by the petitioners, to keep others from entering the same field.

Theoretically, according to Le Chatelier, progress in scientific research, methodically organized, should when plotted against time as abscissa, give a tangential curve with a horizontal asymptote as we approach integral knowledge of the subject studied. In reality progress is made in successive jumps, due to human and instrumental defects. For instance, our first knowledge in stereochemistry was due to the theoretical speculations of Le Bel and van't Hoff. This progress was mainly in organic chemistry, then a period of stagnation with ups and downs occurred, to be followed, around 1900 by another big jump when Alfred Werner developed the stereochemistry of inorganic compounds. A third advance came some fifteen years later when Laue and Debye by means of x-ray diagrams developed new ideas that opened the way to further developments in stereochemistry. And there is no doubt that the end is still far off.

The development of biochemistry in the past twenty years has led to an intense study of the role of trace elements in animal and plant nutrition. The importance of minor nutritional elements has been strikingly illustrated by the classic study on cobalt with which I shall conclude this review of discoveries. In so doing I shall have an opportunity to mention a small contribution of my own to biochemistry. The time I spent on cobalt was very brief, yet in the twenty-five years that have elapsed since I wrote a brief note on "Nitroso R-salt, a new reagent for the detection of cobalt" this compound has been widely used for the estimation of cobalt in plant material and in soil. (Cf. Stiles, *Trace Elements in Plants and Animals,* Macmillan, New York (1946) p. 51). Quantities as low as 0.5 μg can be determined in this way.

Looking through the literature I noticed that alpha-nitroso beta-naphthol is used as a precipitant for cobalt. It then occurred to me that by introducing sulpho-groups into the compound a *soluble* cobalt compound might be formed. Hence I proceeded to choose from the known naphthol sulphonic acids one that was readily available and easily purified. The choice fell on R-salt (sodium 2,3,6, beta-naphtholdisulphonate). This yielded a stable yellow nitroso salt which answered the purpose and has since been used extensively as a sensitive test for cobalt, even in the presence of other metals. I did not pursue this work further and thus missed the opportunity to develop the subject of quantitative colorimetry and what has also become a large field, the search for organic reagents useful in quantitative analysis.

Little or nothing was known in the early twenties of the role of trace elements in biologic activity, and it was not until ten to fifteen years ago that certain diseases in animals were definitely traced to a deficiency of so-called trace metals, such as copper, cobalt, nickel, zinc and manganese.

The following data on cobalt as an essential element in animal nutrition were taken from a recent article of O. Baudisch in the *Journal of the American Medical Association,* [vol. 133, pp. 59-66, (1943)].

It was known, as far back as 1807 that domestic animals, especially sheep in southern Scotland, suffered from a disease called "pining". In order to cure the animals they were shifted to a more succulent pasture grown on limed soil. A similar sickness was later observed in New Zealand where it was called "bush sickness". The loss of animals through this malady was so serious that the Australian government initiated research to discover the cause of this disease.

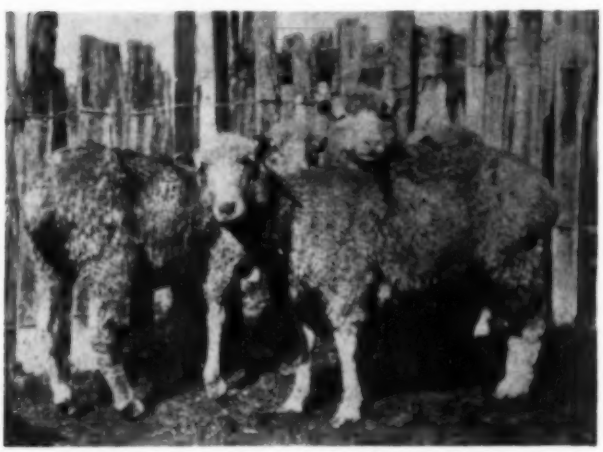
In 1900, Gilruth of the New Zealand Department of Agriculture reported that in localities where the disease occurred there were both "healthy" and "unhealthy" lands and that vegetation grew as luxuriously on one as on the other. It was further observed that the symptoms of the disease were similar to those ordinarily found in nutritional anemia. This, obviously, pointed to a possible iron deficiency. It was then found that massive doses of iron were often useful but not always. It seemed that some unknown constituent was present in some of the limonite used as fertilizer and absent in

others. The Australian government thereupon gathered iron ores from different parts of the world and used these on different acres of unhealthy land.

The iron mineral which was found to be most beneficial to the sheep and gave the best results in preventing bush sickness was next subjected to analytical fractionation on a large scale comparable to the fractionation of uranium ores by the Curies in their efforts to concentrate radium. This costly and tedious work finally led to the conclusion that cobalt was the lacking element. Iron minerals that did not cure bush sickness were extremely low in cobalt while those which prevented the trouble contained much larger amounts of this metal. Furthermore, soils in bush sickness areas contained only a trace of cobalt as compared with those in healthful areas.

Finally, in 1937, Kidson in New Zealand found that soils affected with bush sickness had often less than 2 parts per million of cobalt. It is amazing to find how infinitesimally small are the amounts of cobalt needed in comparison to iron, manganese, copper and zinc where at least a hundred times this amount is demanded. According to Askew, another New Zealand investigator, a sheep needs 0.04 mg. of cobalt daily. Although cobalt can be readily detected in the soil and in the spleen and liver of sheep by nitroso R-salt, it would be extremely difficult to ascertain its presence accurately in the grass which sheep need for their daily feed. Thanks to the work of Baudisch and his co-workers there are now organic reagents like *o*-nitrosophenol which are able to link cobalt in a ring structure and hold it. In this way it can be extracted from grass in sufficient amount to be determined either by spectroscopic or by colorimetric methods.

With this final example of a discovery which was the result of long-continued painstaking research by a large group of investigators I must conclude this brief survey of discoveries, confirmed and unconfirmed. For obvious reasons it was confined mainly to the field of chemistry. ●



AUSTRALIAN SHEEP afflicted with "Bush Sickness."

State Academy of Science

(*Continued from Page 85*)

the field of special meetings for student scientists was held in Boston last December. The executive committee of the American Association for the Advancement of Science sponsored a Junior Scientists Assembly for the first time. While this meeting was essentially an experiment in science education, it gave promise of greater significance.[2]

One phase of scientific work that has been somewhat neglected in the past is that of the teachers of science in the secondary and elementary schools. It is recognized today as never before that the teacher of science is the focal point of interest in the development of the scientists of tomorrow. Without the informed and enthusiastic teacher of pre-college youth we can never hope to lead the world in its scientific activities. Our science teachers dare not be mere drill masters; for they are dealing with the potential leaders of our civilization. Their profession calls for imagination coupled with scientific thoroughness leading to the ultimate goal of producing an independent citizen in a free society.[3]

Teachers of science, whether in the pre-college or the college areas, should be able to look to the state academy of science as an organization for their mutual benefit. Here they can study their particular problems and present their ideas to other scientists. Only in such an organization can so wide a variation in interests and achievements be found. The academy includes in its membership many who have already made significant contributions to the advancement of scientific knowledge as well as many others who are still looking forward to the publication of their first brief paper. As a general organization the state academy of science is concerned with advancing knowledge in all areas and in encouraging the scientific education of the people.

The state academy of science as an organization that has for its main objective the diffusion of knowledge in all departments of science can well serve as a coordinator of the many separate local and special scientific organizations. Too often small groups or clubs in a particular community or in neighboring communities work at cross purposes when they could work together more successfully through a central organization. The state academy is the ideal agency for such coordination of effort. However, the academies often have not taken the lead in such coordination of activities because their volunteer officers were too much occupied with their own duties and professions. For this reason a large and active membership can be helpful. If each member will accept his own share of responsibility for the advancement and promotion of science in his state, the academy can be of real service. Too often we join organizations just for what we can get out of them rather than for what we can contribute. After all, no organization can be successful on a large scale unless its members are willing to give their time and talents to its purposes.

The *Pennsylvania Science News-Letter* is an example of one attempt to coordinate the work of local science groups. It can be most effective for this purpose if all interested members will see that news of scientific interest and news concerning local science groups in the state is given to the editor of the News-Letter. This is one service of the academy that is widely recognized as being of real value. Such a news service coupled with the publication of an annual *Proceedings* with its scientific papers gives the members full value for the small membership fee, but there are many other recognized values.

Perhaps the greatest single benefit the state academy offers its members is the opportunity it provides for fellowship and exchange of ideas with others who may or may not be interested in the same phase of scientific endeavor. It is of great importance that each individual interested in his own education and in the education of his fellowmen make every effort to learn what others think and feel. The state academy of science provides an excellent opportunity for associations that encourage such learning. The chance to become acquainted with fellow scientists is an opportunity that one should prize. The spring and summer meetings are especially helpful in making such personal contacts. In this respect as in so many others the individual member secures benefits from his membership in direct proportion to the effort and interest that he exerts.

The state academy of science movement is one that began many years ago but has been developing more and more rapidly in recent years. While the state organizations have made many contributions already to the advancement of science, they are potentially capable of even greater efforts. Their interstate cooperation through the Academy Conference sponsored by the American Association for the Advancement of Science provides an opportunity for the exchange of ideas, thus promoting further the diffusion of scientific knowledge. All scientists and all persons interested in any of the many phases of science are urged to become active members of their own state academy of science. ●

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Scientists Must Be Human

(*Continued from Page 79*)

only one value and that is the value of challenge. It challenges the scientist to prove and demonstrate it. He counts his progress and success in terms of his ability to do just that. He may work for years upon the supposition that a certain theory may be true, but he never believes it until he is able to demonstrate its validity.

Not only the element of practicality, but also the element of objectivity is at the heart of this method. The scientist takes pride in the fact that his method is absolutely impartial. It seeks truth, let the chips fall where they may. If the path of pursuit cuts directly across our well-worn prejudices or cherished traditions, it really doesn't matter. The incidental damage which may be done to these is much more than offset by the value of the new discoveries. Objectivity has no time for sentiment. Facts are facts and must be dealt with accordingly, entirely apart from emotional reactions.

Of course we want our science to be practical and objective. Otherwise it would not be science. The greatest contribution which science has given to our civilization is its method of thought and procedure, and at the

heart of that method lie the twin characteristics of pragmatism and objectivity. This is as it should be.

But when we project the implications of these characteristics to their ultimate conclusion, we find that they also contain within themselves the greatest danger of possible world destruction. The greatest danger of world destruction does not lie in supersonic rockets, guided missiles, or atom bombs, *per se*. The greatest danger of world destruction lies in the concepts of uncontrolled pragmatism and objectivity. These two characteristics of scientific procedure have enabled science to make its greatest contributions but, uncontrolled, they are the world's most dangerous concepts.

Uncontrolled pragmatism ends in acts of expediency. Consider, for example, the answers which are given in justification of the dropping of the "A" bombs on Japan. The rationalization is based one hundred per cent upon pragmatic argument. It was the expedient thing to do. This can be proven beyond the shadow of a doubt. But this expedient, pragmatic act has raised questions in the realm of ethics and morals which are not easily answered. No matter how ably we defend the act on a practical basis, we still cannot quiet the persistent inner feeling that somehow it was not right. Yet on the other hand, to follow in the way of pure pragmatism left no alternative. That act stands today as the ultimate in the course which is dictated by practical expediency. But it will stand as the ultimate only until a more potent weapon than the atom bomb is discovered and an opportunity for its use is created. The concept of uncontrolled pragmatism contains within it the inminent possibility of the destruction of our world.

The other basic characteristic of the scientific method —objectivity—is also a dangerous tool when not tempered by moral, ethical, and spiritual controls. Uncontrolled objectivity soon loses its humanity. It has no place for such qualities as sympathy, mercy, tolerance, and understanding. Again turning to the war for example we can, from a purely objective point of view, fully justify the death chambers used for the old, the infirm, and the crippled. Of course the idea is utterly abhorrent to our sensibilities, but such sensibilities are not objective in nature. Objectively these persons were of no value to the state. They consumed more than they produced. They were in misery. They were better off dead. Therefore, why not take the initiative and put them quickly out of their misery and relieve the world of the burden of caring for them?

These are extreme examples but what we are saying through them is that these most useful tools of science —pragmatism and objectivity—must have adequate controls if they are not ultimately to become the source of our destruction. The world is at the mercy of the scientist and its only guarantee of safety lies in the humanity of the scientist. As a pure act of self-preservation, if for no other reason, scientists of the future must be human.

The scientist dares never forget that he is responsible for what he creates. He can no longer isolate himself in cold objectivity and continue to turn out weapons for world destruction. He is not merely a spectator on the world scene. The scientist cannot be segregated from the human being. As a human being the scientist is an integral part of our civilization with his own life as much at stake as the life of any other man. These facts should lead the scientist to long, deep, and sober reflection upon the worth of a man as a child of God created in His image and likeness. The scientist who studies the vastness of the universe loses perspective entirely, so far as his own worth and importance are concerned, until he remembers that through his God-given powers, he is the astronomer. Likewise the scientist who studies the chemical and physical structure of our world may lose perspective except he reflect upon the fact that man is a living soul.

Every true scientist, regardless of his protests to the contrary, is essentially an idealist. That is to say, he lives by faith. He searches for the invisible and the undiscovered because he has faith to believe that they exist. But we have reached the place where, unless his faith reaches into the realm of the spiritual as well as the natural order, that which the scientist discovers is destined to destroy our world and the scientist along with it. If the world goes to war again, the chief target of the enemy will not be the military leaders, but the scientists.

All of this serves to point up the truth that the world of today can no longer afford uncontrolled pragmatic objectivity even in science. In fact the world cannot afford to have scientists at all except they be, first of all, men and women of the highest integrity and character; except they be men and women of high ideals and strong purpose determined to devote their scientific knowledge and skills to the enrichment of human life rather than its destruction. The world can afford only scientists who are sufficiently human to recognize their responsibility to the Divine. We may summarize the thesis of this article by saying that if our civilization is to endure, the scientist must, in the words of Dr. Millikan, "learn to walk humbly with his God." ●

★ ★ ★ ★

"The two great pillars upon which all human well-being and human progress rest are (1) the spirit of religion, and (2) the spirit of science, or knowledge. It is primarily to promote and strengthen the second of these that the world's universities and research institutions exist.

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ROBERT A. MILLIKAN
The American Digest
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The G-E Colorscope is provided with light sources which produce each of the three primary colors in mixing colored lights: red, green, and blue. The intensity of each lamp can be individually controlled by means of a separate switch and variable resistor. Relative intensity of each of the three lamps is indicated by the brightness of the three small lights

mounted above the viewing screen. This screen is divided into three sections. The two smaller ones on either side are illuminated with artificially-produced daylight to provide the standard comparison color. The center and larger section of the screen is illuminated by the light coming from the three primary-colored lamps.

Dimensions: 8¼x12½x9½ inches. Net weight, approximately 10 pounds.

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